COMBUSTION

JUL 2 1936

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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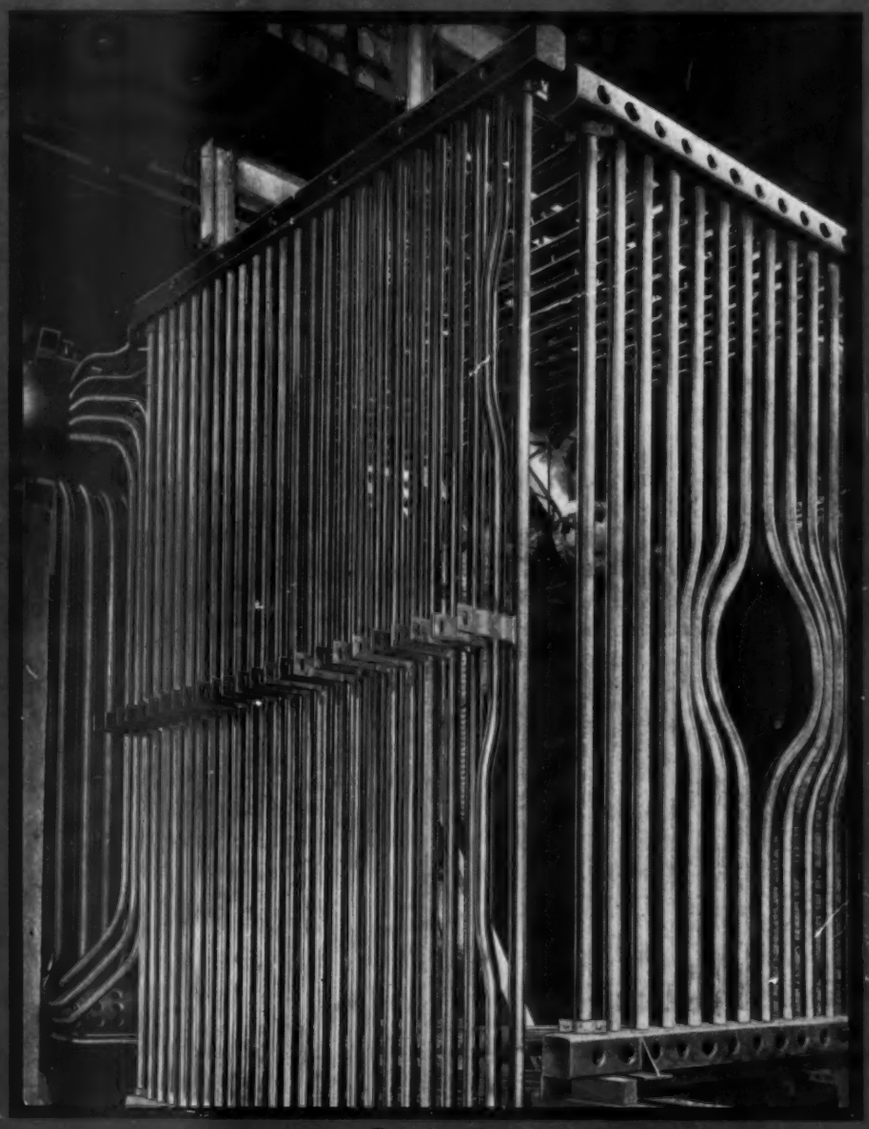

Construction view of a late steam generator showing furnace walls and drums in background

World Power Conference

Developments in the Battle Against Corrosion

NUMBER FOUR

. . . of a series of advertisements in which subjects of current interest to utility engineers and consultants are briefly reviewed and present trends indicated. Subjects to be covered are listed below but deviations may be made either in sequence of list or titles.

Superposition • ***Furnace Design***

Heat Recovery • ***Heat Cycles***

Boilers for High Pressures and Temperatures

Availability of Modern Boiler Units

HEAT CYCLES

In the United States power generation through the medium of steam has thus far been restricted to the application of cycles employing boilers of conventional design, that is, boilers having natural circulation with visible water level maintained within fixed limits and consisting of an assembly of drums and tubes, or drums, tubes and headers.

Designs employing forced circulation have been widely discussed but thus far have had no commercial application in American practice. It would seem to be the general feeling of engineers in this country that although some of the more highly developed of such designs may have attractive possibilities, they have not as yet demonstrated advantages over modern conventional designs that justify their adoption.

The mercury-steam binary cycle is now in its third decade of development. There have been several notable installations, but as yet this cycle is not available to the general field. Furthermore, the high efficiency advantage, which made it attractive at the time of its inception, has been much reduced as a result of improvement in the steam cycle and the increase of operating pressures and temperatures.

For the moment there appears to be no reason to question the continued domination of boiler units of conventional designs. With increase in pressure and temperature, modifications have become essential, but fundamentally the designs remain unaltered.

Progress in the development of steam cycles has been fully covered in articles by F. H. Rosencrants published in COMBUSTION, May 1931 and April 1934. More recently the pressure for superposed installations has become established at a point between 1200 and 1500 lb, with a few exceptions in which the pressure adopted has been in the 700 to 900 lb range. The latter range would appear to have some advantage except as influenced by a demand for the greater capacity available as a result of increased pressure. The low-blading efficiency of existing low-pressure turbines is also an influence favoring the higher pressure.

Few commitments have been made in the past few years for large high-pressure units for other than superposed installations. Where entirely new turbine equipment exhausting to a condenser is involved, there seems to be good reason for favoring a pressure in the range from 650 to 850 lb with a temperature up to a maximum of perhaps 950 F without reheating. Commitments have recently been made for new installations within these limits. With the very high-blading efficiency available in current turbine designs, the moisture content of the steam at the exhaust and its influence on maintenance make higher pressures unattractive.

There appears to be no likelihood in the near future of a demand for pressures above 1500 lb. The urge at the moment is for higher temperature. A pause in this development at the level of 900 to 950 F is now indicated. The opportunity afforded by such a pause for the consolidation of practice in details of design and the proving of suitable materials is highly desirable.

The conclusion to be reached from consideration of recent past and present practice is that the straight-through regenerative steam cycle without reheat—with its proven advantages of simplicity, dependability and high efficiency—will occupy for some time to come the dominant position it now holds in American practice. Higher temperatures await the development of materials and design suitable for their use.

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COMBUSTION ENGINEERING COMPANY, INC.

200 MADISON AVENUE • NEW YORK

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME EIGHT NUMBER ONE

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H. STUART ACHESON, *General Representative*

ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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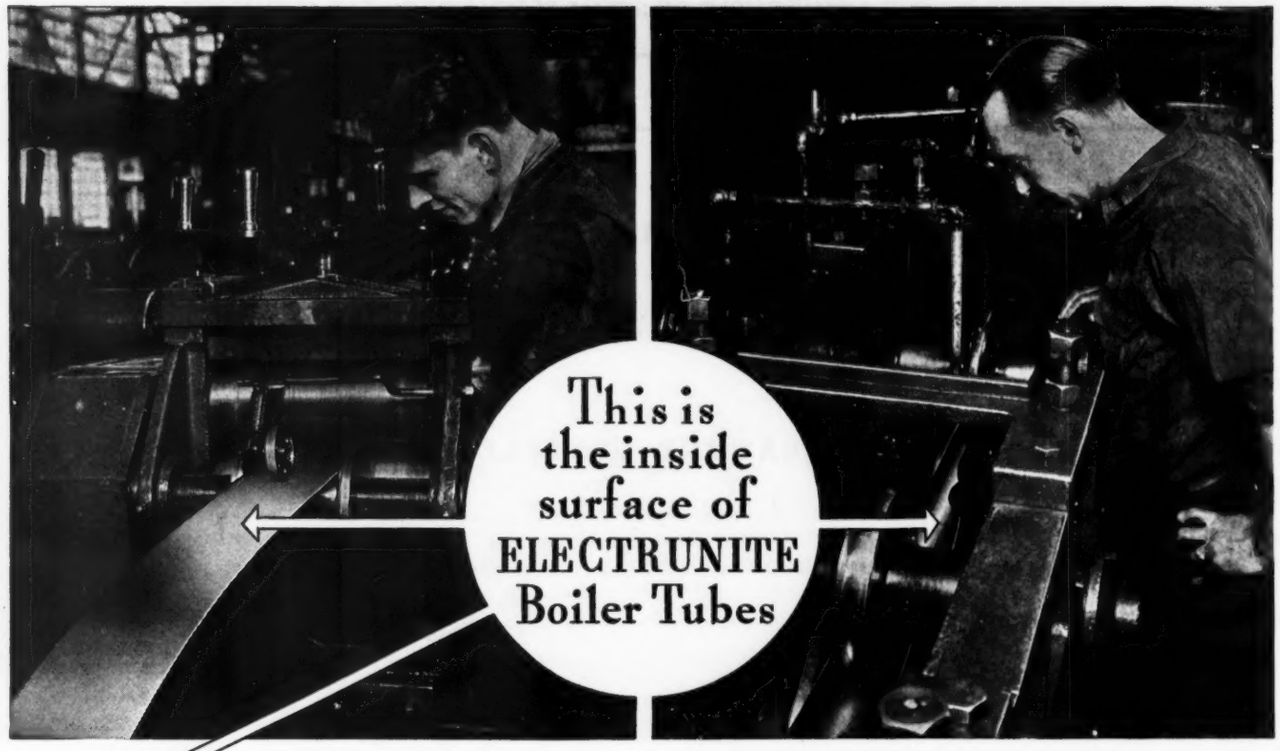

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EDITORIAL

Federal Power Commission Rate Survey

The Federal Power Commission has just issued a 255-page report (Rate Series No. 4) dealing with rates for electric service to commercial and industrial customers. The three previous reports, in this nationwide survey, dealt with domestic rates in communities grouped as to population. It is noted from the present report that large light and power customers, while making up only 1.2 per cent of the total number, utilized 51.3 per cent of the total energy sold and accounted for 26.6 per cent of the revenue. Small light and power customers (exclusive of residential service) were 15.3 per cent of the total number, utilized 15.9 per cent of the total energy sold and accounted for 26.8 per cent of the revenue.

This survey which was authorized by Congress about two years ago, is the first comprehensive tabulation of electric rates that has been made available for general use. It provides a valuable reference, especially for those in the large industrial consumer class—a class which is competitive with privately generated power. In this respect the explanations of special contracts, demand and load factor features, fuel clauses, etc., will be found most helpful.

One, however, should be careful in making comparisons between rates in different localities, as local conditions not apparent in the schedules listed may account for a considerable difference in rates. In other words, perusal of the schedules emphasizes the futility of attempting to apply "yardsticks."

Station Performance Here and Abroad

Elsewhere in this issue is a tabulation of British power station performance for 1935 taken from the Annual Report of the Electricity Commission. Compared with the report of the previous year it shows a steady trend toward improvement. The Battersea Station, which leads the list with a thermal efficiency of 28.59 per cent for the year at a load factor of 68.1 per cent, is somewhat under that of the new Port Washington Station at Milwaukee which has shown the highest performance to date in this country with an average of over 30 per cent for five months and over 31 per cent for the month of April of this year with a load factor of 72.4. The Port Washington Station, however, has the advantage of a higher cycle efficiency inasmuch as it operates at 1325 lb pressure whereas Battersea operates at 650 lb. Both stations produce a kilowatt-hour on less than a pound of coal.

Of the 266 British stations whose performance is reported the average of twenty-seven was 1.34 lb of coal per kilowatt-hour whereas the average for the whole group was 1.54 lb. The only comparable figures published in this country are from the reports of the U. S. Geological Survey covering totals for 3800 plants, large and small and supplying power for public use, which show an average of 1.47 lb per kilowatt-hour.

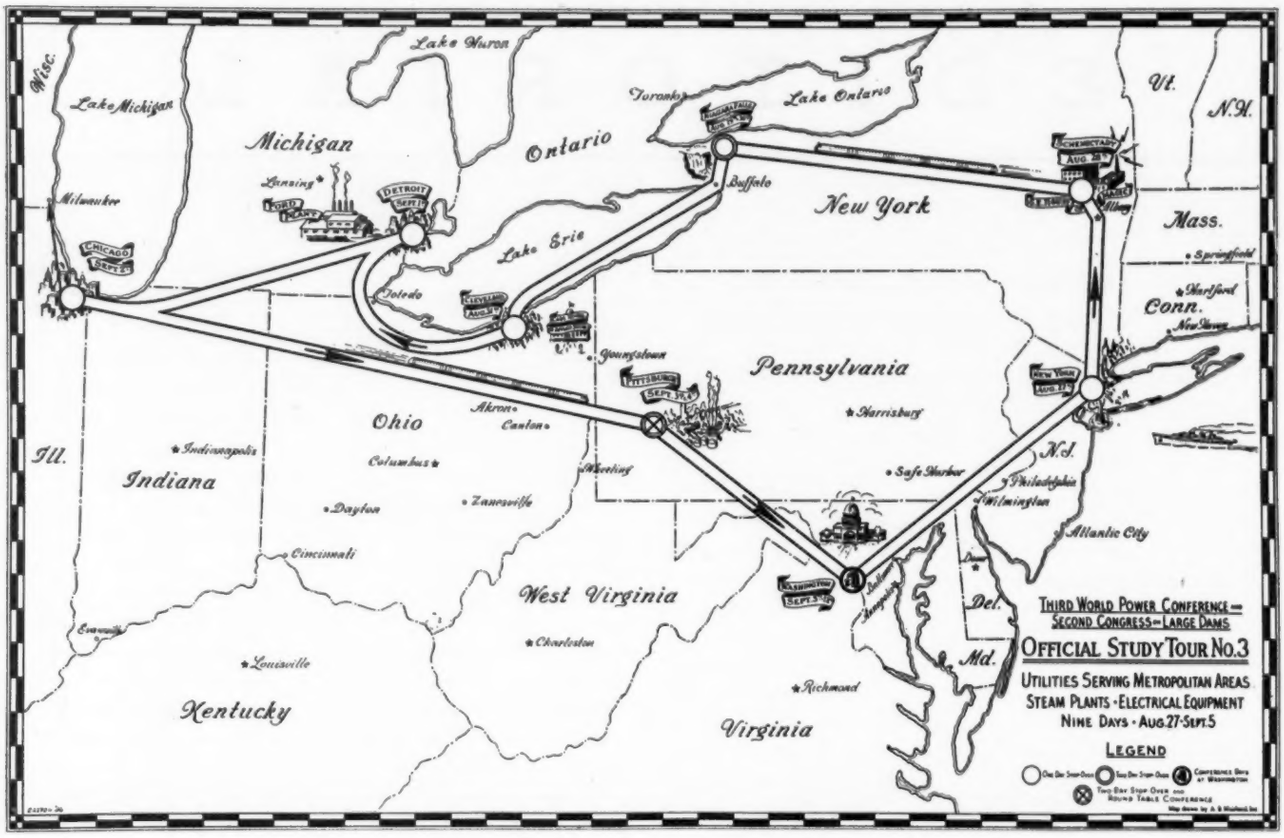
While data have been published from time to time on individual plant performance much of this information is too scattered for convenient reference. In view of this it would be helpful if a report such as that issued yearly on the performance of British power stations could be made available through some properly constituted body concerning the outstanding American Stations. It is recognized that certain objections to such a plan exist from a policy standpoint, but the advantages should outweigh the disadvantages.

Stack Discharges Receiving Attention

Renewed activity in steam plant construction appears to have revived interest in atmospheric pollution—a matter that remained more or less dormant during the depression, except for routine enforcement in certain localities and some P.W.A. surveys in metropolitan areas which, however, were handicapped through employment of inexperienced personnel.

With present designs of furnaces and fuel-burning equipment and experienced operation, the "smoke problem," as formerly regarded, no longer exists in connection with the larger stations, but consideration still has to be given to the discharge of cinders, dust and noxious gases. Many of the larger installations have already put in, or are making provision for the inclusion of, electric precipitation equipment and those of lesser size for cinder catchers and dust collectors of the cyclone type to cope with the first two items; and the third, the discharge of noxious gases, is now receiving serious consideration in anticipation of a probable public demand for such elimination, as has exifted for some time in England. A few companies have installed gas washers but these are still largely in the experimental stage.

The public has little conception of the engineering efforts and expense that have gone into a solution of the stack discharge problem. It might have been better had such information been more widely disseminated to the end that there might be fuller appreciation of the fact that both engineers and managements have been awake to the situation, that substantial progress has been made and that a cleaner atmosphere involves expense that forms a legitimate cost of generating electricity.



WORLD POWER CONFERENCE

PLANS for the Third World Power Conference to be held in this country during September are now practically completed.

As previously mentioned in these columns, the Washington program will be devoted largely to economic subjects pertaining to energy sources, their conservation, development and utilization, while the technical features will be covered by a series of pre-Conference and post-Conference study tours to industrial centers, research laboratories and outstanding power plants. These tours will be supplemented by twenty-two Round Table Conferences at which selected topics will be discussed as well as differences between European and American practices. Arrangements for the Study Tours and Round Table Conferences are being handled by a Coordinating Committee made up of representatives of the founder engineering societies, the Edison Electric Institute and certain associations covering fields included in the scope of the Conference.

To review briefly the background of the World Power Conference, it is a federation of National Committees of some fifty countries. Plenary meetings are held every six years and sectional, or more limited, meetings are held in the interim. The first general Conference took place in London in 1924, the second in Berlin in 1930 and the third will be in Washington in 1936. Sectional meetings have been held in Basle, London, Barcelona, Tokio and Stockholm. Also, under its auspices has been organized the International Commission on Large Dams which held its first congress in Scandinavia in 1933 and will hold its second congress in conjunction with the present Conference.

The American National Committee consists of Secretary Ickes, chairman, Dr. W. F. Durand, vice-chairman, Morris L. Cooke, chairman of the Executive Committee and J. D. Wolfsohn, executive secretary. Arrangements are being handled by the Executive Committee, made up of the heads of certain government bureaus having to do with power and fuel, and a number of well known engineers, industrialists and utility executives. O. C. Merrill, is Director of the Conference, and in immediate charge of the arrangements.

Washington Program

At Washington coal, oil gas and electricity will be taken up in turn with analyses of the problems of their production, transportation, conservation and use, as well as the business structure of the industry and its relations with labor, government and the consumer. Consideration will be given to both private and public ownership, the operation of gas and electric utilities, and their regulation. National and regional planning will be treated primarily in their relation to the conservation of sources of power. It is planned to have every participating country submit a paper on each of the topics listed that has bearing on its power problems.

The schedule of Conference Sessions and topics for the Washington meeting is as follows:

MONDAY, SEPT. 7

10:00 a.m.—Registration
8:30 p.m.—Opening Session

TUESDAY, SEPT. 8

10:00 a.m.—"Organization of Production, Processing and Distribution of Coal and Coal Products"
"Organization of the Production, Processing and Distribution of Petroleum and Petroleum Products"
(Dams Congress)—"Design and Waterproofing of Shrinkage, Contraction and Expansion Joints"
2:00 p.m.—"Significant Trends in the Development and Utilization of Power Resources"
(Dams Congress)—"Study of the Facing of Masonry and Concrete Dams"

WEDNESDAY, SEPT. 9

10:00 a.m.—"Organization of the Production, Transportation and Distribution of Natural and Manufactured Gas"
"Organization of Private Electric and Gas Utilities"
(Dams Congress)—"Special Cements"
2:00 p.m.—"Collections, Compilation and Publication of Statistics with Particular Reference to International Use"
"Public Regulation of Private Electric and Gas Utilities"
(Dams Congress)—"Geotechnical Studies of Foundation Materials"

THURSDAY, SEPT. 10

10:00 a.m.—"Organization Financing and Operation of Publicly Owned Electric and Gas Utilities"
"Conservation of Coal Resources"
"Conservation of Petroleum and Natural Gas"
2:00 p.m.—"National and Regional Planning and Their Relation to the Conservation of Natural Resources"
(Dams Congress)—"Calculation of the Stability of Earth Dams"

FRIDAY, SEPT. 11

10:00 a.m.—"Planned Utilization of Water Resources"
"Regional Integration of Electric and Gas Utility Facilities"
2:00 p.m.—"Utilization of Small Water Powers"
"Rationalization of Distribution of Electric Energy and Gas"
"Rural Electrification"

SATUDAY, SEPT. 12

10:00 a.m.—"National Power and Resources Policies"
2:30 p.m.—Closing session

Among the Americans who will present papers dealing with these selected topics are:

"Trends in the Utilization of Power Resources," by Dr. H. S. Person, Consulting Economist, and Dr. Vannevar Bush, Dean of Engineering, M. I. T.

"Internal Use of Statistics," by Dr. E. Dana Durand, Commissioner, U. S. Tariff Commission.

"Production and Distribution of Coal and Coal Products," by Isador Lubin, also the National Coal Association.

"Production and Distribution of Petroleum and Its Products," by Myron S. Watkins, N. Y. U.; E. L. deGolyer, President, Felmont Corporation; J. Noel Robinson, V.-P., Tidewater Oil Co.; R. E. Hardwicke, and Joseph E. Pogue, Consulting Engineer.

"Production and Distribution of Gas," by Judson C. Dickerman, Federal Trade Commission; also American Gas Association.

"Organization of Private Electric and Gas Utilities," by Robert E. Healy, Member of S. E. C., and Jas. F. Fogarty, Pres. North American Co.

"Public Regulation of Private Electric and Gas Utilities," by James C. Bonbright, N. Y. Power Authority and William E. Mosher, Syracuse University; and John E. Zimmermann, Pres. United Gas Improvement Co.

"Organization of Publicly-Owned Utilities," by E. F. Scattergood, Bureau of Power & Light, City of Los Angeles.

"Planning for the Conservation of Natural Resources," by Stuart Chase, Economist; and W. S. Finlay, Jr., Pres. West Penn. Electric Co.

"Planned Utilization of Water Resources," by Arthur Morgan, Chairman, T.V.A.; and Harrison G. Roby, Byllesby Eng. & Mgt. Corp.

"Utilization of Small Water Powers," by Dr. H. H. Bennett, U. S. Dept. of Agriculture.

"Regional Integration of Electric and Gas Utility Facilities," by Basil Manly, Vice-Chairman, Federal Power Commission; and Geo. N. Tidd, Pres. American Gas & Electric Co.

"Rationalization of Distribution of Electric Energy and Gas," by J. D. Ross, S. E. C.; and Norman R. Gibson, Vice-Pres. Niagara-Hudson Power Corp.

"Rural Electrification," by Dr. H. A. Morgan, Director, T.V.A.; and Hudson W. Reed, United Gas Improvement Co.

"National Power and Resources Policies," by George Soule, New Republic; and Floyd L. Carlisle, Niagara-Hudson Power Corp.

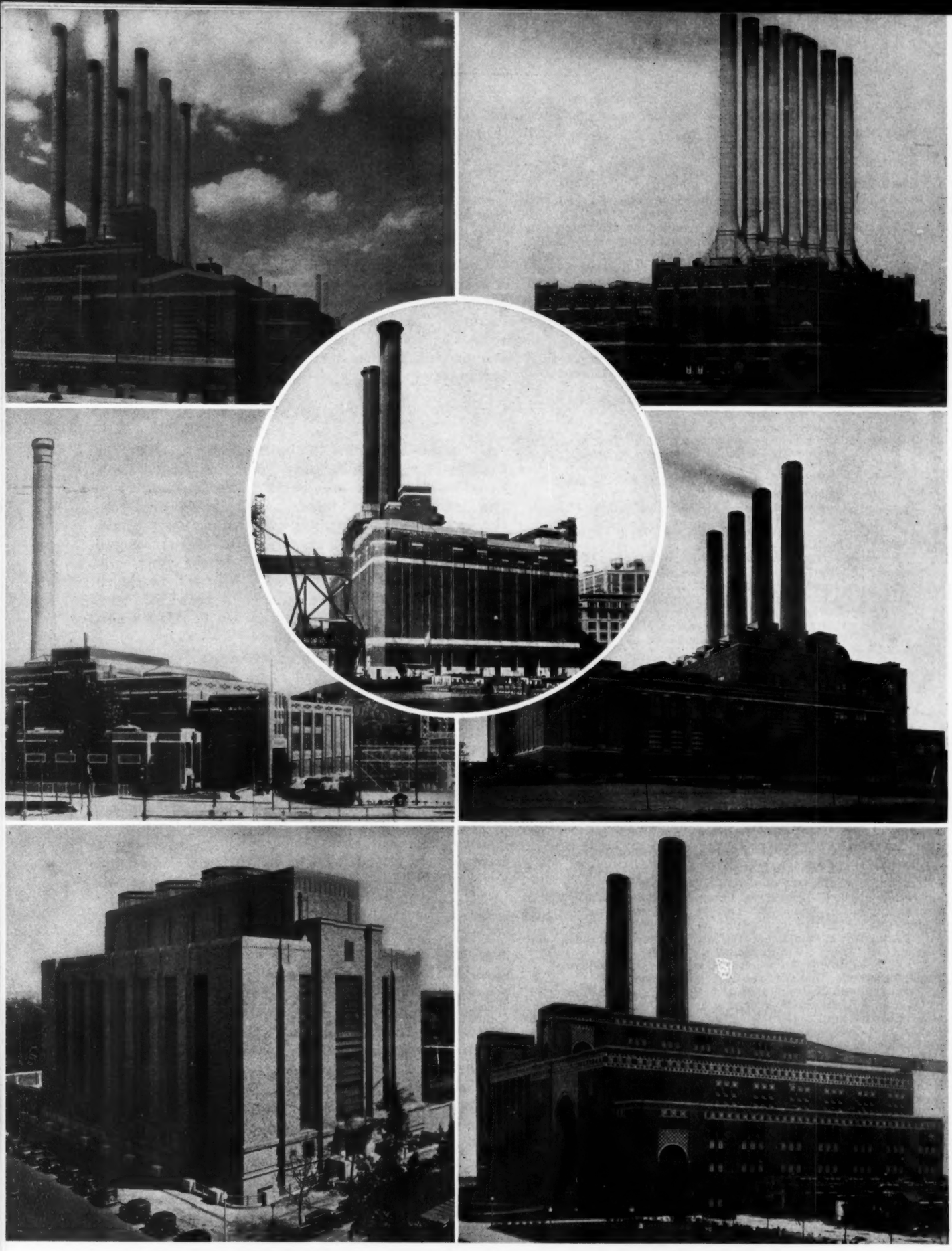
Concurrently with the Washington program there will be a number of exhibits by industry associations among which will be that of the American Boiler Manufacturers Association in two bays of the National Museum. This will include models and prints of new outstanding installations of steam generating units and fuel burning equipment.

Technical Program

Of particular interest to the engineers attending the Conference will be the Study Tours and Round Table Conferences. There will be four pre-Conference and four post-Conference tours, practically in duplicate; this arrangement having been rendered necessary by the fact that some of the foreign delegates will arrive well ahead of the Washington meeting whereas others will not arrive until the day before. There will be eleven pre-Conference and a like number of post-Conference Round Table Discussions. In addition to this a transcontinental tour has been planned.

TOUR NO. 1 will deal with mineral resources of power, embracing coal, oil, gas and power from internal-combustion engines. After a visit to the Bayonne Refinery the party will leave New York on Aug. 31, arriving at Detroit on Tuesday morning Sept. 1, where a visit will be made to the Rouge Plant of the Ford Motor Co. and the Detroit Edison Co. Leaving Detroit by boat that evening the party will reach Cleveland next morning and will visit the works of the Winton Engine Company and the research laboratory of the Case School of Applied Science. From Cleveland the party will go to Pittsburgh to inspect the Research Laboratory of the Gulf Refining Company, the Mellon Institute, Carnegie Institute and the U. S. Bureau of Mines. Opportunity will also be afforded for visiting industries around Pittsburgh as well as oil and coal mining properties. Saturday Sept. 5 will be devoted to Round Table Conferences of the coal oil and gas groups.

TOUR NO. 2, embracing dams, hydro plants, T.V.A. and hydraulic research will leave New York by boat for Boston on Friday, Aug. 28, and will devote the following day to a program at the Massachusetts Institute of Technology, covering research on soil erosion, dams, cavitation, etc. Leaving Boston that evening the delegates will go to Niagara Falls to inspect the hydro plants on both the American and the Canadian sides. From here the trip leads to Pittsburgh where visits will be made to the Mellon Institute and the New Kensington Laboratory of the Aluminum Company of America where studies have been made of concrete arch dams and the use of rubber models. Leaving Pittsburgh late that evening the party will entrain for Zanesville where Sept. 2 will be devoted to inspection of the soils laboratory and work of the U. S. Engineer Corps. From here the delegates wil go to Knoxville to spend Thursday and Friday inspecting the T.V.A. development and devoting Saturday to a Round Table Conference.



Some of the Plants to Be Visited on the Steam Plant Tours

(*Upper left*) Rouge Power Plant of Ford Motor Company, Detroit, the largest industrial power plant containing the largest high-pressure high-temperature steam-generating unit now in operation. (*Upper right*) Conners Creek Plant of the Detroit Edison Company, recently rebuilt for higher pressure and greatly improved economy. (*Oval*) East River Station of the New York Edison Company, one of the boilers at this station has attained an output of 1,270,000 lb of steam per hour. (*Center left*) Port Washington Station of the Milwaukee Electric Railway & Light Company, a single boiler, single turbine installation operating at 1325 lb pressure and holding the record of 10,946 Btu per kw-hr for a whole month. (*Center right*) Avon Station of the Cleveland Electric Illuminating Company. (*Lower left*) New U. S. Central Heating Plant at Washington, D. C. (*Lower right*) State Line Generating Station near Chicago which contains the largest turbine-generator unit.

TOUR No. 3, embracing steam plants, electrical equipment, transmission and distribution, engineering education and research, will leave New York for Albany by night boat on Aug. 27 and spend the following day at the works of the General Electric Company where its research laboratory and the steam-mercury installation will be inspected. Proceeding from here to Niagara Falls it will inspect the steam plants of the Buffalo General Electric Company and certain chemical industries and leave on Sunday, Aug. 30 by boat for Cleveland where visits will be made to Nela Park Research Laboratories, the Case School of Applied Science and to power stations of the Cleveland Electric Illuminating Company. Opportunity will also be afforded those interested to see the high-pressure plant of the Firestone Tire and Rubber Company at Akron. From here the party will go to Detroit to visit the Ford plant and the Conners Creek Plant of the Detroit Edison Company. Chicago is the next stopping point where visits will be made to State Line Generating Station and the laboratory of the Portland Cement Association Station and a side trip to Milwaukee to inspect the new Port Washington Station of the Milwaukee Electric Railway & Light Co. From Chicago the party will go to Pittsburgh, arriving on the morning of Sept. 3 and will visit the Research Laboratory of the Gulf Refining Company, the U. S. Bureau of Mines, Carnegie Institute, the Westinghouse Works and local power stations. Round Table Conferences of the steam, electrical and management groups will be on Saturday.

TOUR No. 4, dealing with diesel and steam locomotion, railway electrification and railway equipment, will make a trip from New York to Philadelphia on Aug. 28 to visit the Baldwin Locomotive Works and the Budd Mfg. Co., builders of stream-lined diesel-electric trains. Returning to New York the party will leave for Schenectady, to visit the American Locomotive Works and the General Electric Company, then go to Chicago to inspect the Pullman Shops and other interesting points in that railway center. Thursday, Sept. 3 will be devoted to Round Table Discussions and the party will proceed to Pittsburgh to visit the Westinghouse Air Brake Company, the Aluminum Corporation of America, the Union Switch & Signal Company and the Gulf Refining Laboratories.

While in New York the delegates will be afforded an opportunity to visit the power stations of the New York Edison Company, the Brooklyn Edison Company, the New York Steam Corporation, the Public Service Electric & Gas Company of New Jersey and the Gilbert Station at Holland, N. J., also the power plant of the Hotel New Yorker and that of R. H. Macy, the two last employing both steam and diesels.

The dates given apply to pre-Conference tours. The post-Conference tours will start from New York on Sept. 14 and 15 and will cover the same points of interest, except that in some cases the routing will be changed and the Round Table Conferences held at different places. For instance, it has been arranged for post-Conference Tour No. 2 (hydro) to spend Sept. 15 and 16, respectively, in Montreal and Ottawa as guests of the Canadian Government and all the tours will take in Niagara Falls at the time of the A.S.M.E. Regional Meeting where joint sessions will be held with the respective professional divisions of that Society on Sept. 17–19. Tour 1 will hold its Round Table Conference at that place on Sept. 19 and Tour 3 (covering steam plants) will hold its Round Table Conference in Philadelphia on Sept. 24.

Niagara Falls Meeting of A.S.M.E.

The sessions of the A.S.M.E. Meeting at Niagara Falls which have been arranged to fit in with the World Power Conference tours are as follows:

THURSDAY, SEPT. 17

9:30 a.m.—Power Session
"Current Practice and Trends in American Power Plants," by A. G. Christie, Johns Hopkins University
"Superposition," by E. H. Krieg, American Gas & Elec. Co.
"Power Station Design for Pressures from 500 to 800 lb having medium size units," by James A. Powell, E. M. Gilbert Engineering Corporation

9:30 a.m.—Transportation Session

THURSDAY AFTERNOON

2:00 p.m.—Foreign Practice Session
"German Boiler and Turbine Practice," by Dr. Otto Schoene, Univ. of Berlin; also a discussion of British boiler and turbine plants.

FRIDAY, SEPT. 18

9:30 a.m.—Power Session
"Design and Operating Problems When Using Gas and Oil Fired Boilers for Standby Steam Electric Stations," by V. F. Estcourt, Pac. Gas & Elec. Co.
"German Furnace Design and Combustion," by Dr. Schulte

9:30 a.m.—Hydraulic Research Session
"American Hydraulic Laboratory Practice," by Leslie J. Hooper, Worcester Polytechnic Institute
"Laboratory Research Projects of the Corps of Engineers, U. S. Army," by Lt. Francis H. Falkner.

2:00 p.m.—Hydroelectric Session
"American Hydroelectric Practice," by A. C. Clogher, Ch. Hyd. Eng. Electric Bond & Share Co.
"Canadian Hydroelectric Practice," by Dr. T. H. Hogg, Chief Hydraulic Engineer, Hydroelectric Power Commission of Ontario

In arranging for topics to come up for formal discussion at the various Round Table Conferences thought has been given to those things in which both foreign and American practices lead so that each may learn from the other. Moreover, in order not to parallel the theme of the Washington program economic phases have been avoided. Those in a position to speak authoritatively on the subjects selected will be asked to lead off with ten or fifteen minute talks before the general discussion. Interpreters will be on hand at each of the Conferences.

The topics that have been tentatively selected for discussion at the Round Table Conference on Steam Plants include: (1) "Recent Practice in Welded Drum Construction"; (2) "Washing Stack Gases"; "Exit Furnace Temperature as a Basis of Boiler Design with Reference to Preventing Slag Accumulations"; (3) "Steam Washing"; (4) "Experience with the Operation of Special Boilers Such as the Benson, La Mont, Loeffler, Schmidt, Sulzer and Velox"; (5) "Adaptability and Limitations of Binary Cycles"; (6) "Experience with Materials for High Steam Temperatures."

At the present writing indications are that between 600 and 700 delegates and guests will come from abroad.

Arrangements for handling and entertaining the delegates in each of the cities visited will be handled by local committees and the American Express Company will take charge of all travel and hotel matters. A feature of the New York entertainment will be a large banquet on Sept. 13 or 14 with the New York Edison Co. as host.

Developments in the BATTLE AGAINST CORROSION

By V. A. ROHLIN* and C. E. JOOS†

The authors discuss the principles and problems involved in the mechanical deaeration of boiler feedwater to meet the exacting demands of present practice, and describe two late types of deaerating heaters developed by one manufacturer. One of these is of the tray type in which the flow of water and steam are parallel and the other employs the counterflow principle and deaerates by spraying and atomizing without the use of trays.

THE trend toward higher operating pressures, present boiler designs and cleaner tube surface resulting from improved chemical treatment of feedwater have combined to establish a new and higher standard for the performance of deaerating feedwater heaters. At the same time manufacturers and engineering organizations have conducted independent investigations into the accuracy, susceptibility to error and refinements of the Winkler iodimetric test for measurement of dissolved oxygen. The results of this work have opened the way toward establishing more definitely the conditions under which corrosion may be expected to occur, as well as providing the means whereby the performance of deaerating equipment may be more accurately gaged.

In the period during which this progress has been made it has been the endeavor of the manufacturers of such equipment to meet the more modern conditions so completely as to avoid the need of fixing dissolved oxygen by chemical means. This has resulted in the development of two types of mechanical deaerators, each capable of oxygen removal to a point beyond measurement even by the improved Winkler test, and under practically all conditions obtained in power plant operation.

It is noteworthy that the development of these two types has proceeded along diametrically opposed lines, one being a tray type in which the flow of water and steam are parallel and the other employing the counterflow principle and deaerating by spraying and atomizing without the use of trays.

Parallel-Flow Tray-Type Deaerator

In common with older equipment from which it developed, this design embodies four essential elements:

1. Means for distributing water over the trays.
2. A nest of heating trays to heat the incoming water to practically the saturated temperature of the steam with which it is in contact.
3. A second nest of trays identified as separating trays, the function of which is to effect the release and escape of bubbles of fine gas thrown out by the heating process against the forces of viscosity and surface tension.
4. A vent condenser for conserving the heat of the vent vapors.

Fig. 1 illustrates the downflow deaerator with the component parts indicated. Its distinguishing feature in contrast to earlier designs is in the admission of steam to the top of the heating tray section instead of from the bottom or side. The path of the steam flow is downward through both tray stacks. Traveling at all times at a velocity considerably in excess of that of the water, it repeatedly cuts across the finely divided stream of water falling from the spilling edges of one layer of trays to the next layer below it, thus insuring maximum contact without retarding the flow of water. Intimate contact is brought about by staggered trays as illustrated by Fig. 2.

Much of the steam is condensed in the heating trays. The balance used in the deaeration process, still moving at high velocity, since the steam drawn through the air separating trays is many thousand times the volume of the gas removed, sweeps through the lower trays and carries away the bubbles of gas as they are brought to the surface by agitation and tumbling of the water. The vented steam with the separated gases is removed from the heater above the water surface and flows to the vent condenser where the non-condensable gases are separated from the steam vapor and released to the atmosphere.

Based on the fundamental laws governing the solubility of gases under these conditions, study has been applied to the practical problems of extending the water surface and agitating it to remove the minute bubbles of free gas thrown out of solution by the deaerating process, and controlling the distribution and flow of water despite the high steam velocities employed in commercial equipment.

Experimental deaerators, constructed to determine the effect of various steam flow directions or paths on the distribution of water over the trays, demonstrate that the downflow principle not only eliminates the disturbance and uneven distribution common with older designs but actually assists in spreading the water uniformly on the trays regardless of flow rate and thereby promotes even distribution. Study has also been applied to tray design to effect division of water in fine

* Work Manager, Cochrane Corporation, Philadelphia, Pa.
† Manager of Water Purification Division, Cochrane Corporation, Philadelphia, Pa.

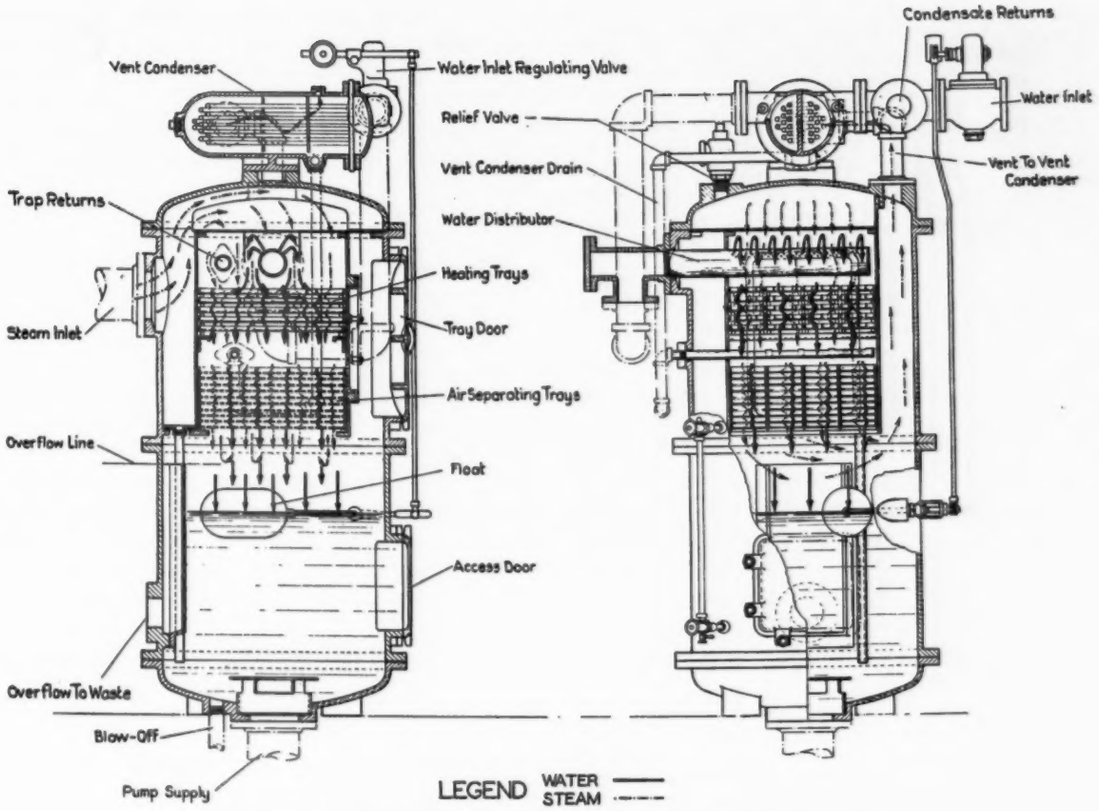


Fig. 1—Downflow deaerator with component parts indicated

sheets and frequent tumbling to expose new and fresh surfaces to the high velocity scrubbing steam.

The theory covering early designs, i.e., that it was necessary to pass all of the incoming steam through the air-separating section to produce sufficiently low partial gas pressure, has been displaced by the knowledge that partial pressure, although important, is only one of the factors involved. Obviously, it must be controlled and reduced to an extremely low value if the most efficient performance is to be achieved. However, the premise that the proper amount of steam to pass the air-separating trays is all the steam to be employed in heating—whether that amount be large or small—is discarded and in the present equipment the rate of steam flow through the air-separating section is governed by the requirement for the deaeration process. This requirement is met by the design of vent condenser to assure a sufficient flow of steam to reduce the partial gas pressure to an unmeasurable quantity.

The design of the air-separating section, therefore, is no longer governed by the requirement to provide enormous areas for steam flow beyond the need to scrub effectively the water and govern partial gas pressure, and the designer is free to proportion the air-separating section from the standpoint of breaking up the water in fine sheets and tumbling and agitating it as required in the process for the most effective deaeration.

Jet-Type Deaerator

An even later development employs high velocity jets instead of trays, for finely atomizing the water to be deaerated. This design was brought about by the demand for a deaerating feedwater heater in marine service, the operation of which would not be disturbed by the pitch and roll of the ship. Also, since weight is a consideration in such cases, any reduction that might be made without interfering with deaeration was welcome.

Fig. 4 illustrates the jet-type of marine heater which incorporated a number of novel features making it particularly well adapted for this service. The water to be deaerated first enters the vent condenser at *A* and then passes into the preheating section which is a jet heater at *B*. At this point the water is broken down into a fine spray and heated to within approximately 2 deg of steam temperature and the oxygen reduced to 0.1 to 0.2 cc per liter. The chamber *C* into which the water is sprayed is fitted with sectional baffles so as to insure even water distribution regardless of roll or pitch of the ship. From chamber *C* the preheated water falls on to

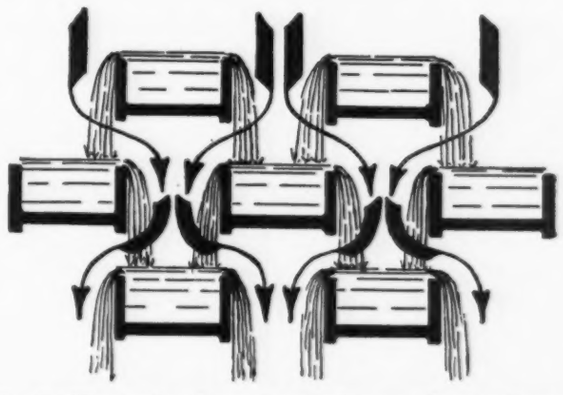


Fig. 2—Illustrating how staggered trays effect intimate contact

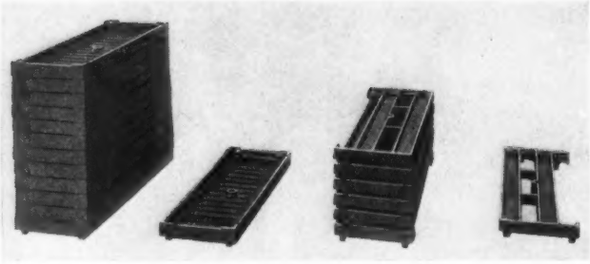


Fig. 3—Trays on right are for heating and water distribution; those on left for air separation

the deaerating jet at *D* at which point deaeration is completed. The path of the steam is into the jet deaerator which is a spring or weight governed valve-like arrangement, so set that there is a constant drop in pressure across it of approximately $^1/_2$ lb per sq in. This causes the steam to issue from the valve at high velocity. The preheated water falls upon the steam jet and is atomized or dispersed so finely that the oxygen is removed. The steam passes around chamber *C*, condenses in preheating the entering water, and the vented steam is taken off at *E*. It will be noted that the jet type of deaerator is well adapted to the employment of the counterflow principle, since the one objection to the employment of that mode of operation is removed, namely, tray displacement and difficulty of evenly distributing water over trays under this condition.

This method of deaeration has been so effective that it has been incorporated as an integral part of hot process water softening equipments. Prior to the development of the jet deaerator, it was necessary to deaerate the softened water in a separate chamber apart from the water softening equipment. This has been because when deaerating a high carbonate raw water the release of carbon dioxide upon heating resulted in an accumulation of deposit on the trays which seriously disturbed water distribution and affected the deaeration process. The use of a separate deaerating heater beyond the water softener has been satisfactory from the standpoint of deaeration but it has been objectionable from the standpoint of installation costs, head room and space requirements. The jet type of deaerator made integral with the hot process softener sedimentation tank deaerates the water after softening and avoids interference from deposits.

Fig. 5 illustrates a hot process softener in which the jet type of deaerator forms an integral part. The operation of this heater is similar to that of that marine deaerator previously described but provides for removal of hardness by chemical treatment and sedimentation before deaeration.

A number of installations of this type of equipment have been made and found to give zero oxygen by the latest technique employed in the Winkler test. This type of deaerating heater has also been applied effectively to the removal of other gases than oxygen. The atomizing element for large capacities is made horizontal and usually hydraulically operated. Fig. 6 illustrates the deaerating element furnished as part of a 32,000 gph hot-process softener.

Aside from the fact that a deaerating heater should reduce the oxygen content to an extremely low limit, consideration should be given to reducing maintenance to a minimum. With ordinary water supplies the cast-iron or steel-plate deaerator with cast-iron trays or working parts is satisfactory. There are, however, special instances, such as where the feedwater is treated to establish lower alkalinities and satisfactory embrittlement ratios where the jet-type deaerator has best filled the need.

Chemical Deaeration

Fixation of oxygen by chemicals is not new, having been used in practice for a number of years. For example, the Lakeside Station of the Milwaukee Electric Railway & Light Company used ferrous hydrate as a means of absorbing oxygen from feedwater as early as 1930. Ferrous sulphate has been used over ten years in conjunction with hot process softeners as a coagulant and a means of absorbing oxygen. Other chemicals, such as alkaline tannates and sodium sulphite, have been applied. The preference for sodium sulphate is due to its comparatively low cost, ease of handling and the fact that in fixing oxygen it leaves only a soluble sodium sulphate which is useful in many plants to increase the sulphate content of the concentrated boiler water to bring about the recommended sulphate carbonate ratios recommended by the A.S.M.E. Boiler Code for protection against embrittlement.

The use of sodium sulphite is justified as an after or supplementary treatment to the older type open heaters that do not reduce the oxygen content sufficiently low to afford complete protection against corrosion, but in the writers' opinion, it is not justified as a substitute for mechanical deaeration when consideration is being given to the purchase of feedwater heating equipment. Generally speaking, the added cost of a deaerating type over a standard open heater can easily be justified. Mechanical deaeration has the advantage of simplicity and greater thermal efficiency, since it operates with zero terminal difference and eliminates chemical dosing equipment and control.

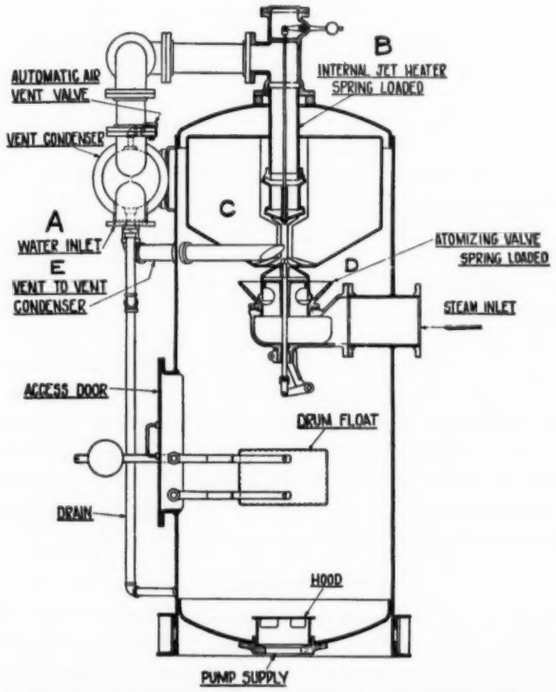


Fig. 4—Section through jet-type marine feedwater heater

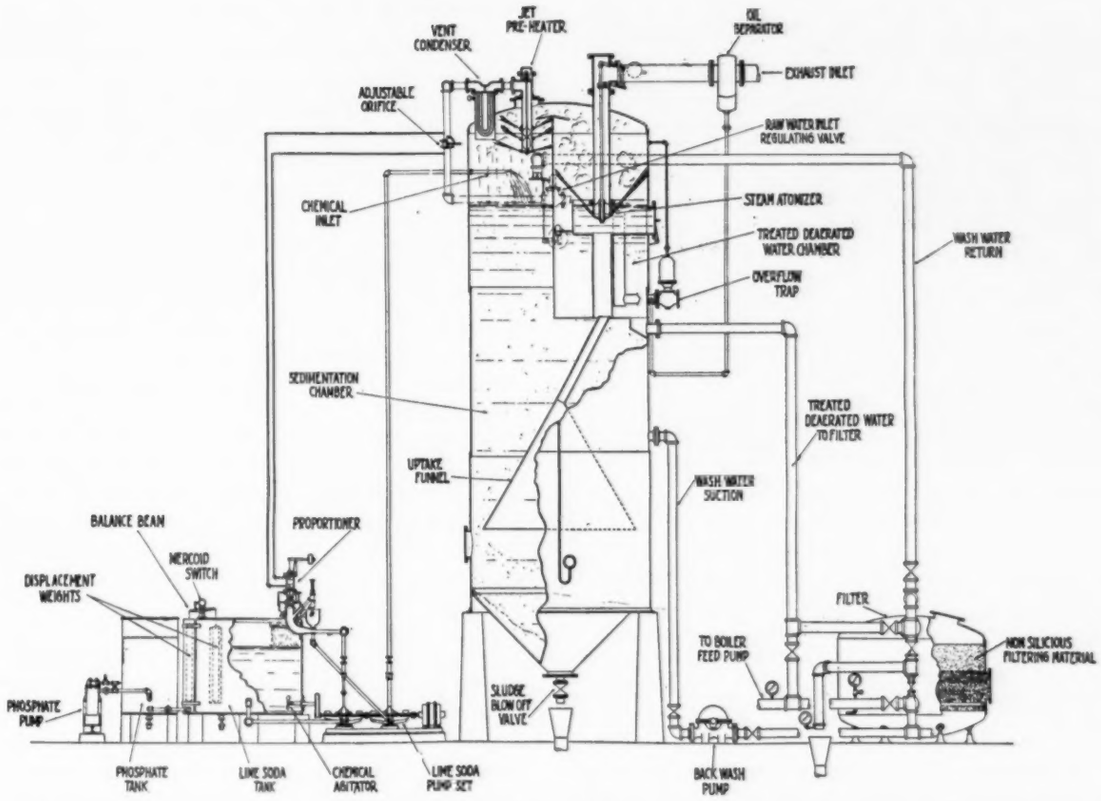


Fig. 5—This represents a hot-process softener of which the jet-type deaerator forms an integral part

Chemical fixation of oxygen as a supplement to mechanical deaeration finds a justified application where cold water is to be deaerated without heating. The process of mechanical deaeration can only be carried out by holding water at the boiling point. To do this with cold water it is necessary to subject the deaerating equipment to vacuum and if deaeration is to be complete such vacuum-producing equipment is necessarily bulky and expensive to operate. Under these conditions it pays to compromise by removing the bulk of the gas from solution by a reasonable vacuum and fixing the remainder of the oxygen by means of chemicals. An industrial plant recently used this combination to advantage to protect a ten-mile pipe line from corrosion. The water was first passed through a mechanical deaerator under moderate vacuum to remove the bulk of the oxygen from saturation. The oxygen remaining was fixed by the addition of sodium sulphite proportioned accurately to the flow of cold water. The installation has been successful in eliminating the corrosion that was progressing rapidly prior to the installation of the combination equipments. Chemical fixation made unnecessary employment of high vacuum producing equipment that would be required alone to reduce the oxygen to the extremely low limit desired, thus saving considerable installation and operating expense.

The application of sodium sulphite must be done with caution and consideration given to the necessary interval of time required for the complete fixation of oxygen as well as accurate proportioning where protection is desired in such equipments as steel-tube economizers, feedlines, etc., since in these equipments there is no opportunity for concentration as in a boiler. The amount of oxygen unfixed in the presence of sulphite cannot be readily determined because of the interference of the sulphite with the Winkler Test. Thus, it is quite possible to have sulphite and oxygen present in the uncombined state without this being detected, as under these conditions a test for oxygen by the Winkler test would indicate zero.

The Winkler Test for Oxygen

Perhaps there is no testing procedure in the power plant that has been under such close scrutiny as the Winkler test for determining oxygen in feedwater.

Advances have been made in the technique to estimate more accurately minute quantities of oxygen ordinarily undetectable by the older procedure. Two praiseworthy papers have been published discussing the need of extreme care in making the estimation.[1,2]

Since this time the Winkler Test has been developed further by A. C. Dresher.[3] In estimating the oxygen content of deaerated feedwaters the titration must be carried out with extreme care as an error in a single drop of titrating solution may correspond to an error of 100 per cent of the oxygen present. Chemists have frequently used very dilute solutions of thiosulphate in conjunction with large samples to reduce the possible error in titration to a minimum. Mr. Dresher has attacked the problem from a different angle and has eliminated the use of the titrating solution entirely. He has found that there is a definite relation between the oxygen content of a sample and the temperature at which the blue color of the iodo-starch reaction first appears. This relationship is clearly shown by Fig. 7.

[1] "The Winkler Test for Determining Oxygen in Boiler Feed Water," by J. D. Yoder and A. C. Dresher, COMBUSTION, April 1934.
[2] "The Determination of Traces of Dissolved Oxygen by The Winkler Method," by M. C. Schwartz and W. B. Gurner, A.S.T.M., Vol. 34, Part II, 1934.
[3] See "Determining Oxygen in Boiler Feedwater—New Method Eliminates Titration," by A. C. Dresher, COMBUSTION, May 1936.

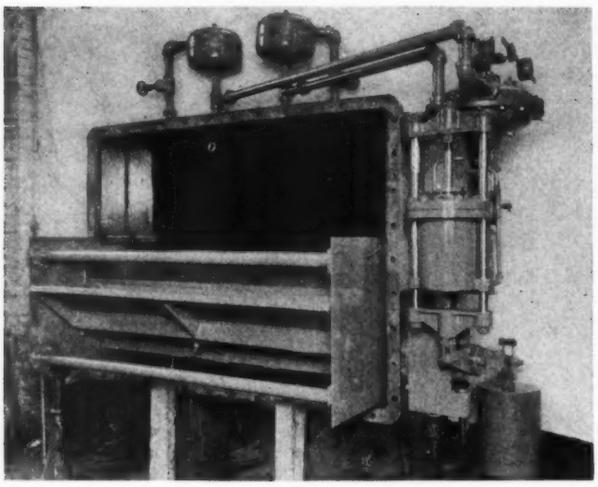


Fig. 6—Deaerating element of a 32,000 gph hot-process softener

On carrying out this method of estimating traces of oxygen the sample is fixed in the customary fashion in accord with the instruction given in the paper previously mentioned by A. C. Dresher and the writer.[1] The temperature of the sample is brought to 120 F and the starch added. If the total oxygen is below 0.195 ml per liter, based on the use of Baker's soluble starch, the solution will remain colorless. The solution is gradually cooled and agitated by means of a thermometer and note taken of the temperature of the first appearance of blue color. Reference is then made to the curve of Fig. 7 for estimation of the oxygen content.

It will be noted that an error of 2 deg at 80 F in reading the thermometer represents an error of only 0.004 ml oxygen per liter, clearly demonstrating the accuracy of the method. The method has been used in practice since its development over a year ago and has been found to be extremely accurate and reliable. Since it eliminates titration and frequent standardization of the thiosulphate solution it is a method that should become popular with power plant operators.

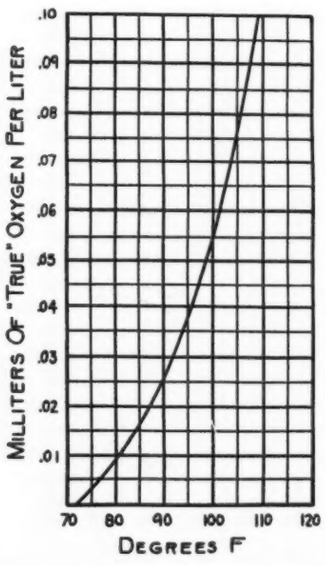


Fig. 7—Temperature at which faint blue color forms gives "true oxygen" of sample. Use Baker's c.p. soluble starch

Paralleling Feed Pumps

The operation of feed pumps in parallel often presents a problem when the several pumps are of different capacities. How this situation is met at the Kips Bay Station of the New York Steam Corporation is related by A. A. Markson in the report of the Steam Station Engineering Committee of the National District Heating Association.

At Kips Bay Station, there are six steam-driven feed pumps, the rated capacities of two being 750 gpm and the remainder 1500 gpm at 425 lb discharge pressure. The discharge of the pumps is through a common header to two risers which feed the boiler loops.

The first thing done to improve the paralleling was to change the hookup of the pressure governors so that the diaphragm loading pressure was applied hydraulically instead of by a spring. The hydraulic balancing pressure is obtained from a bypass connection between the first and last stage through a needle valve on the first stage side adjustable by hand. The adjustment of this needle valve determines the intermediate pressure in the bypass line at the point of supply to the governor diaphragm. When the pump is called on for more water, this pressure decreases, causing the governor to open and supply more steam. If the header pressure changes, all pumps change speed together. In order to show operating conditions, an indicating flow meter is connected to each pump discharge. Where the piping is crowded, as at Kips Bay, the use of hat type orifices was very convenient.

The procedure of pump operation is as follows:

The operator adjusts each governor needle valve till the pumps are delivering the desired capacities. The governors from that point swing the pumps in excellent parallelism to meet the load requirements.

This system has resulted in better feedwater regulation at the station and saved steam by having the desired number and combination of pumps on the line at all times. The operation of the governor by hydraulic pressure assures really parallel regulation and the flow indication informs the operator that the pump is actually delivering the desired quantity.

A. S. M. E. Nominations

Nominations for officers of The American Society of Mechanical Engineers for 1937 were announced at a recent meeting of the Nominating Committee held at Dallas, Texas, during the Semi-Annual Meeting. The nominees are:

President—J. H. Herron, President, James H. Herron Company, Cleveland, Ohio.

Vice-Presidents—J. A. Hall, Professor Mechanical Engineering, Brown University, Providence, R. I.
J. M. Todd, Consulting Engineer, New Orleans, La.
R. J. S. Pigott, Gulf Research & Development Corp., Pittsburgh, Pa.

Managers—E. W. Burbank, District Manager Allis Chalmers Mfg. Co., Dallas, Tex.
K. H. Condit, Editor "American Machinist," New York.
S. W. Dudley, Dean of Engineering, Yale University, New Haven, Conn.

THE BENSON BOILER

By DR. F. MICHEL,

Siemens-Schuckertwerke, Berlin, Germany

Much has been written on the Benson boiler. It has undergone extensive development and fundamental changes since first brought out commercially about twelve years ago. This work has been reported from time to time in the technical press and in papers before foreign engineering societies, but it is believed that this information is more or less fragmentary in the minds of many American engineers and that the author's account of this development work warrants publication. Fully cognizant of the fact that American engineering opinion seems to prefer the conventional type boiler to the forced-circulation European designs, Mr. Michel has been accorded space to enumerate the merits of the Benson boiler and to comment on its commercial possibilities so that the reader may be able to judge as to its relative advantages—Editor.

THE Benson boiler and other special boilers were developed in Germany and to some extent in Switzerland after the war as a consequence of the coal shortage which followed the war-time exploitation of European coal mines.

An efficiency drive induced the development of these boilers because those of the conventional type were then regarded as being unable to operate at pressures higher than around 800 lb per sq in. The initial cost of these special boilers was, in the beginning, considered of secondary importance to the thermal merits of the high-pressure cycle. Subsequently, the conventional boiler extended its field up to 1400 lb per sq in. and eventually higher, and while today the majority of these special boilers may be regarded as satisfactory steam producers, it is vital to their future that they be able to compete successfully with the conventional boiler. To what extent the Benson boiler can do so and its special merits are here discussed.

Earlier Once-Through Boilers

As early as the end of the last century a once-through forced-flow boiler was in operation but experienced tube failures. These were attributed to unequal distribution of the working medium and to steam bubbles adhering to the tube walls, thus causing overheating and burning. Later experimenters with such boilers had similar discouraging results. Hence, the belief became general that steam could not be generated successfully in once-through forced-flow boilers because they had no steam-separating drums.

Mark Benson, therefore, conceived the idea of generating steam in a once-through boiler at critical pressure where no steam bubbling would occur. Thus he hoped to avoid the troubles of the earlier once-through boilers, and also to avoid the expensive high-pressure drums. His seemed a most promising design because it made available steam at any subcritical pressure by throttling and then securing any desired initial steam temperature by reheating, at the same time affording the advantage of high thermal cycle efficiency.

These prospects and the influence of the coal shortage in Germany induced the Siemens-Schuckertwerke of Berlin in 1924 to undertake commercial development of Benson's idea. But the first Benson boilers developed tube failures similar to those of their subcritically operated predecessors. However, the non-existence of actual evaporation due to critical pressure operation overthrew all theories on sticking steam bubbles, and the proper distribution of the flow could be checked by the temperature of the working medium at the outlet of the tubes and elements, because the temperature continuously increased with increasing heat input. After careful investigations a fundamental truth was found.

Fundamental Discoveries

The water-soluble salts contained in boiler feedwater, even if treated, pass through the Benson boiler only partially as a dry dust after the conversion of water into steam at critical pressure, the remainder being deposited on the inner tube walls just about where this conversion is being completed. These deposits due to their poor heat conductivity, are responsible for a considerable increase in tube-wall temperature and thus render the tubes liable to failure if the deposit zone is located in the radiant portion of the heating surface, that is, the combustion chamber. This was the case in the first Benson boilers.

Research in this respect was difficult because actual deposits could never be found in a tube after its failure; for, being water-soluble, they were washed away by the steam and water mixture escaping through the crack before the boiler could be stopped. They could be traced at first only by measuring the electrical conductivity of the working medium as fed into the boiler and as sampled at different points along the fluid path. After this method had shown that and where water-soluble deposits actually occurred it became possible to demonstrate their presence by the following procedure: After a cer-

tain period of operation an experimental boiler was stopped by shutting off the water and fuel simultaneously and evaporating water remaining in the boiler by the heat stored in the brickwork and thus preventing any deposits from being dissolved. Upon cutting out a tube in the suspected zone the expected salt deposits were visible.

As a result the deposit zone was removed from the combustion chamber, on radiant zone, and located in the convection zone where the gas temperatures are low enough not to endanger the strength of the tube walls.

The manner in which it was possible to remove the deposit zone from the radiant heating surface, even in boilers already built, can be seen from Fig. 1 which refers to the boiler of the Hamburg-American liner "Uckermark." The upper view represents a cross-section in perspective with the salt deposit zone in the so-called "Preheater II," corresponding to "Arrangement II" in the lower portion of Fig. 1. Originally, the flow path was in accordance with "Arrangement I" and at that time the salt deposits occurred and caused tube failures in "Radiant Part I." The transfer of the deposit zone into "Preheater II" involved nothing more than rearrangement of the interconnecting piping whereas the heating surfaces as such remained in their original place.[1]

This removal of the salt deposit zone from the combustion chamber involved automatically spreading of a given amount of deposits over a greater tubular surface due to the lower heat intensity in the convection-heated portion; in other words, the formation of thinner deposit layers.

A second conclusion was that the tube failures of earlier once-through boilers were probably due to the same kind of salt deposits. Hence, it was deemed possible to operate the Benson boiler at subcritical pressures provided, of course, that the zone of the salt deposits which were expected to occur at the completion of the subcritical evaporation zone were likewise kept in the convection-heated portion. This proved to be true and since then all Benson boilers have been operated at suitable subcritical pressures. So of Benson's original idea little remains but the name which will be maintained for commercial reasons, the more so as in some cases it may be thermally economical to operate as high as the critical pressure.

How easily the "Uckermark" boiler could be adapted to subcritical operation is shown by "Arrangement III" of Fig. 1. Again, only some interconnecting pipes had to be changed in order to keep the deposit zone in its proper place ("Preheater II") at subcritical operation. It could be kept there at all pressures up to 2800 lb per sq in.

The salt deposits are disposed of when the boiler is stopped by flushing it for a while with feedwater to prevent the otherwise dry tubes from becoming too hot due to the heat from brickwork and baffles. During this process deposits are dissolved and carried off. Benson boilers have been operated continuously in this way for periods up to two months. For longer periods of uninterrupted service a simple scavenging device is provided which allows flushing of different groups of the salt deposit zone progressively while the boiler is under load.

Equal distribution of flow over

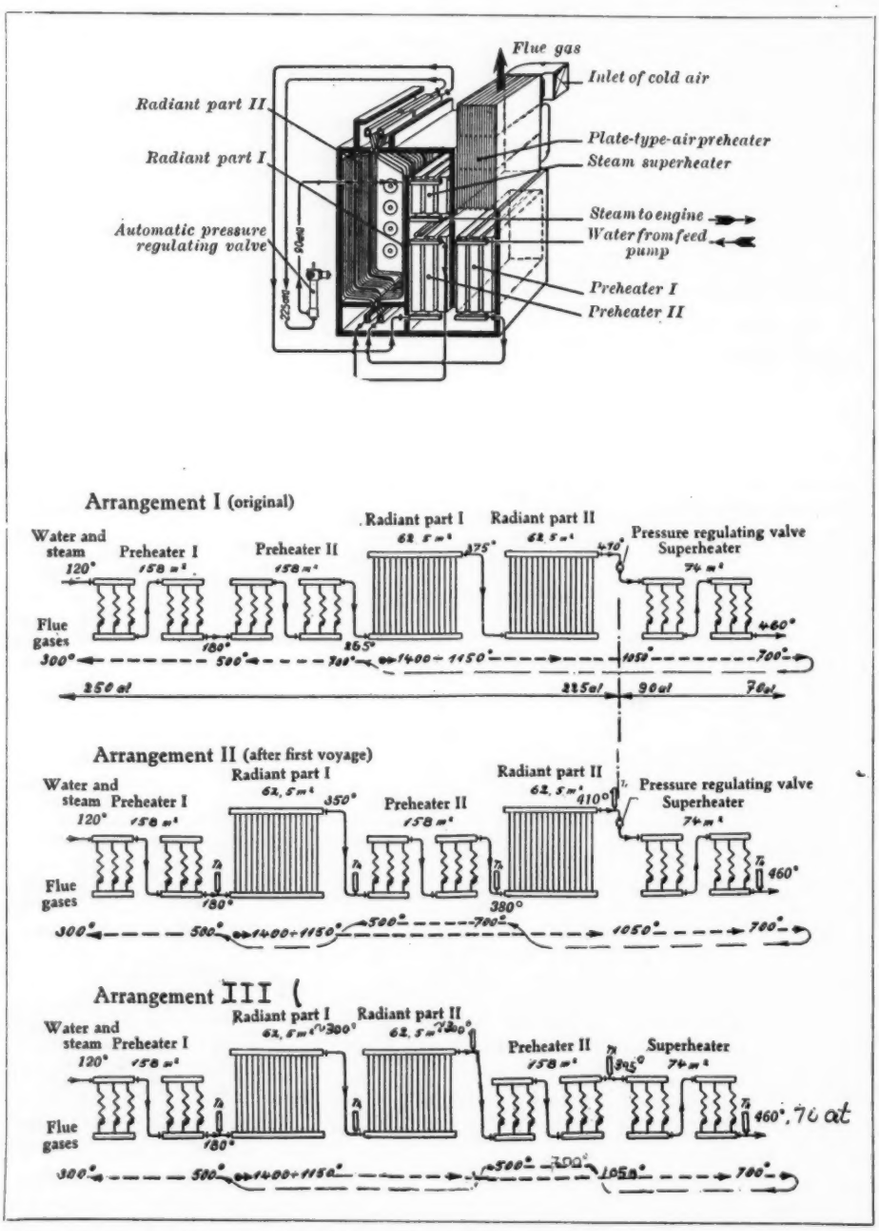


Fig. 1—Cross-section of the "Uckermark"-Benson boiler in perspective and different arrangements of the flow path, the bottom arrangement being for subcritical operation at 1000 lb per sq in.

[1] See "Betrieb und Ergebnisse des Benson-Kessels auf D. Uckermark," by Dr. E. Goos, paper presented at the annual meeting 1931 of the Schiffbautechnische Gesellschaft.

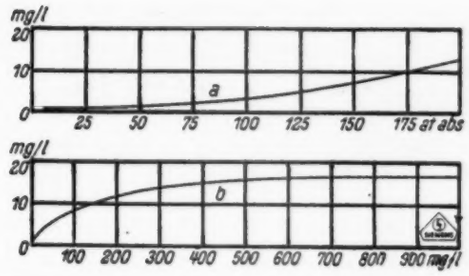


Fig. 2—Salt contents of superheated steam

(*a*) as a function of the operating pressure at 25 ppm feedwater concentration and 800 F; (*b*) as a function of the feedwater concentration at 1400 lb 800 F. Note: mg/l = ppm.

all tubes connected in parallel is assured by the arrangement of mixing headers. These headers are required anyway from the construction point of view because in passing from the economizer, for instance, to the radiant portion it is much simpler to collect the water in one inter-connecting pipe than to transfer it in twenty or more parallel tubes. Here it is in order to refer to the important research in the United States on the flow distribution in once-through boilers by H. L. Solberg, G. A. Hawkins and A. A. Potter,[2] which confirmed the experiences gained with the Benson boiler.

It became apparent that subcritical operation enhanced the commercial prospects of this boiler, for the parts of a critical-pressure boiler would have to be dimensioned according to that pressure though the turbine might be operated at much lower pressure, whereas the subcritically operated Benson boiler of today has its tube walls dimensioned just as any conventional boiler corresponding to the turbine operating pressure.

Benson versus Other Types

Compared with the other so-called special boilers, the Benson is the only one which has no drums, no recirculating pumps, an unlimited fuel range, a salt deposit zone located outside the furnace, is available for any operating pressure from, say, 400 to 3200 lb per sq in., and does not need outside steam for starting. Moreover it is able to compete with the conventional boiler because it is much lighter and requires less space (of special importance in the marine field) and for these reasons should be somewhat cheaper.

The A.S.M.E. Boiler Code stipulates a tube wall thickness proportional to the pressure and the outside diameter of the tube and inversely proportional to the stresses allowed for a given material. Consider the evaporating surface of a conventional boiler and that of a Benson boiler. For pressures higher than 1000 lb per sq in. and high outputs the conventional type would use outside tube diameters of at least 3 in. whereas the Benson needs only $1^1/_4$ in. O.D. or less due to forced flow. Assuming the same amount of active tubular evaporating surface in both cases and the same operating pressure this surface for the Benson boiler weighs less than half that of the conventional boiler because the wall thickness is less than half that of the latter. Since there is no reason why the Benson boiler should not use the same tube material as the conventional design for equivalent temperature conditions—the more so as it uses forced flow—the active evaporating tubular surface of the Benson boiler should be proportionally cheaper. Moreover, water and steam drums are completely eliminated. Economizer and superheater being forced flow heating surfaces of the conventional boiler may be assumed as of equal weight and cost with that of the Benson. While it is true that the actual boiler evaporating surface of the conventional boiler is becoming less, the higher the pressure, as the latent heat to be added in that surface decreases with increasing pressure, this does not apply to the large amount of surface serving as downcomers and interconnecting piping. These downcomers are required in the conventional type to secure the necessary circulating forces.

As to feedwater it can be stated that the Benson boiler can use any water suitable for a conventional boiler under similar working conditions. No special advantages are claimed in this respect but on the other hand no disadvantages have been experienced.

Carry-over

The Benson boiler carries over less salts to the turbine than are fed into it since there are deposits in the tubes and, even at the highest ratings, there is no priming and foaming. The amount of salt carried over as a function of the salt concentration in the feedwater is shown in Fig. 2 (curve *b*). It should be noted that even with a 1000 ppm feedwater only about 17 ppm are carried over. Curve *a*, Fig. 2 refers to a 25 ppm feedwater and shows the salt concentration of the superheated steam as a function of the pressure over a very large range. At 1000 lb per sq in., for instance less than 2 ppm are carried over.[3]

But for any type of boiler the quantity of salts carried over is not as important as whether they are of the kind that will stick to the blades; see Straub's paper on "Cause and Prevention of Turbine Blade Deposits."[4]

The temperature of the steam leaving the superheater in the Benson boiler is independent of load and pressure. It is also not responsive to variations of furnace exit temperature caused, for instance, by slag deposits delayed

[2] *Trans.* A.S.M.E., Vol. 56 (1934), p. 841.

[3] See lecture on "Developments of forced circulation with regard to the Benson boiler in the Past and Future," by H. Gleichmann, abstracted in COMBUSTION, March 1934, p. 25.

[4] *Trans.* A.S.M.E., Vol. 57 (1935), No. 8 and its discussion as to the Benson boiler by F. Michel (*Trans.* A.S.M.E., Vol. 58 (1936), No. 4, p. 330).

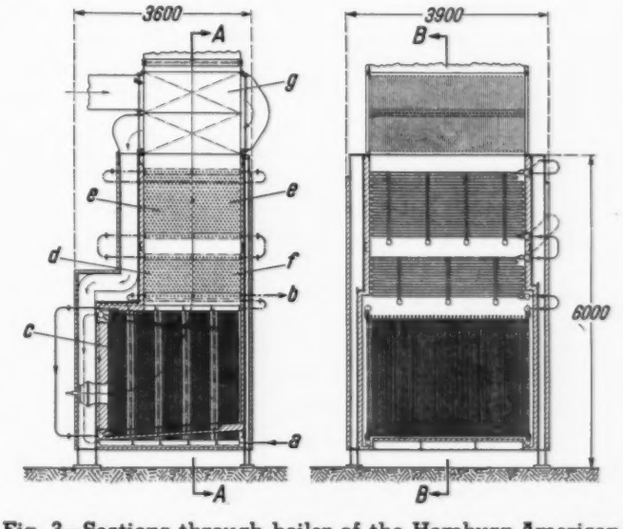


Fig. 3—Sections through boiler of the Hamburg American Liner "Potsdam," 53,000 lb of steam per hour at 1200 lb pressure and 880 F.

(*a*) feedwater inlet, (*b*) superheated steam outlet, (*c*) radiant heating surface, (*d*) contact heating surface, (*e*) salt deposit zone, (*f*) superheater, (*g*) air preheater.

combustion or abnormal excess air. Temperature of the outgoing steam is simply a function of the fuel-water ratio and is controlled by adjusting the fuel quantity in response to it. A reheater if used would be controlled by means of a damper and bypass.

Cycle Comparison

In the extremely high pressure range, 1500 to 3200 lb per sq in., the Benson boiler is in a practically non-competitive class. The utilization of such pressures means a noteworthy gain in economy in many cases where a predetermined quantity of lower pressure steam has to be provided either for operating existing turbines (superimposition of old plants) or for supplying heat for industrial purposes. It is believed that the utilization of such high pressures has a future in large base load central stations yet to be built.

Variable-Pressure Operation

A third conclusion from the investigations previously mentioned was the conception of variable pressure operation which is advantageous for peak load conditions (either on land or on naval ships). The idea is to operate at average load (cruising speed in the case of ships) with a moderate pressureof, say, 600 lb per sq in., representing the most thermally economical pressure for this load and to meet the few hours of high peak load of, say, four times the average output by increasing the pressure, perhaps up to as high as 2400 lb. Since the inlet pressure of a given turbine is proportional to the load the latter pressure would permit forcing four times the steam quantity through the turbine. Thus the turbine blading could be dimensioned for the base-load conditions and the condenser would arbitrarily be laid out for the base-load steam quantity. Consequently, the condenser pressure would increase to a value just sufficient to avoid too high a moisture percentage during the short time peak-load operation.

Since the initial steam temperature is held constant the adiabatic heat drop over the entire load range remains practically constant. Moreover, since the thermodynamic efficiency of the turbine depends upon the flow, which in cubic feet of steam per second is constant, this efficiency remains equally constant at all loads. Both of these facts entail a constant amount of work actually done in the turbine in Btu per pound of steam independent of the load.

Calculations have indicated that such a station could be built for half the investment cost of a conventional station referring in both cases to the peak load capacity in dollars per kilowatt. The Benson boiler alone can be built with customary efficiency as light as 0.7 lb per pound of steam generated. Furthermore for maneuvering in marine work the Benson boiler can be easily adjusted to variable temperature operation in order not to overheat the reverse turbine; see Hodgkinson's paper on the subject.[5]

That the Benson boiler has proved satisfactory in actual service at sea is shown by the 44,000-lb per hr installation in the Hamburg-American liner "Uckermark," a 6000 hp cargo steamer which has been in regular service between Hamburg and the Dutch East Indies since 1930. As a result of its performance the Hamburg-American Line decided to equip its new 18,000-ton turbine-electric driven Far-East passenger liner "Potsdam" exclusively with four Benson boilers each supplying about 53,000 lb of steam per hour at 1200 lb pressure and 880 F temperature for the 26,000 hp drive. This boat has been in regular service since the middle of 1935 with the boilers operating satisfactorily. A cross-section of one of these boilers is shown in Fig. 3 and the bare boiler as erected in the shop is shown in Fig. 4. The convection tube bundles are supported by water carrying tubes connected in the boiler circulation and thus serving also as heating surface.[6]

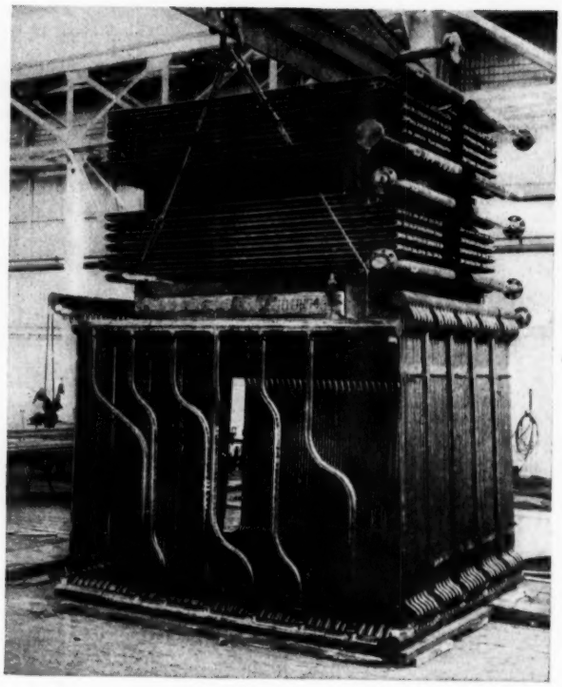


Fig. 4—Benson boiler for the Hamburg American Liner "Potsdam," as erected in the shops of Blohm and Voss

Installations and New Orders

The two first commercial Benson boilers in the Cable Works of Siemens-Schuckert in Berlin are well known through earlier publications. One has a capacity of 66,000 lb per hr and the other of 100,000 lb per hr. They have been in service since 1927 and 1929, respectively. The 265,000-lb per hr unit in Langerbrugge, Belgium, is also well known and has operated since 1930. These boilers are all pulverized-coal fired. They were originally built for critical pressure but are now operated subcritically.

At the present there are three more pulverized-fuel fired boilers under construction for an industrial plant in the Ruhr Mining District, each to generate 155,000 lb of steam per hour at about 1400 lb pressure. They will go in operation August 1936. Also two Benson boilers optionally gas or oil-fired will be ready for operation this summer for the test pits of the Muelheim turbine works of Siemens-Schuckert, and more recently an order was placed for a 110,000-lb per hr unit to be erected in the industrial plant of the Siemens Cable Works in Berlin. Other projects are under consideration.

[5] "The Benson Boiler and Its Application," by Francis Hodgkinson, COMBUSTION, Vol. 6 (1935), No. 9, p. 21.

[6] For more detail information see "Ostasien-Schnelldampfer Potsdam," by B. Bleiken, *Zeitschrift* VD1, Vol. 79 (1935), p. 969.

INCIPIENT BOILER FAILURES

By D. L. ROYER, Chief Engineer
The Ocean Accident and Guarantee Corp. Ltd.

While lack of replacement and proper maintenance during the depression is responsible for the unsafe condition of many boilers now in operation, defects in the design and installation of many of these older boilers also presents a serious hazard. The author reviews these defects, shows that reduction in allowable operating pressure due to age does not compensate for such conditions, and concludes where inspection reveals the necessity for major repairs, replacement often proves more economical and the most satisfactory solution.

IT is difficult to obtain complete information regarding the true condition of the boilers being operated in the United States at the present time, due to the fact that not all of these boilers are insured and many do not come under city or state boiler inspection departments. From the data available, however, it is evident that the gravity of the situation is not fully appreciated.

The condition of the boilers that come under some recognized inspection service may be summarized as follows:

Approximately 50 per cent of the boilers in use are defective to some degree. These defects are of such a nature that they will become serious unless remedied.

About one boiler in seven is seriously defective.

One boiler in one hundred and seventy is definitely unsafe because of serious physical weakness.

The condition of boiler plants as indicated by these figures is not entirely due to lack of maintenance resulting from depressed economic conditions, although it is evident that the "depression" has been responsible for many failures to properly maintain boilers and their appurtenances and for the continuance in service of many obsolete boiler plants that would have been replaced by safer and more economical installations if conditions had been more nearly normal. It also appears that the present situation results more or less directly from changes in design brought about by the normal development in the use of steam in this country. In this connection a brief analysis of this development during the past 40 years is of interest.

When steel for boiler plate became available about fifty years ago, boilers of the horizontal return-tubular, Manning vertical-tubular and Scotch marine types became popular and were built in intermediate and fairly large sizes. The water-tube boiler had proved reliable and economical, but many engineers preferred the fire-tube type for various reasons. The demand for increased pressures following the development of the high-speed engine and turbine brought the water-tube boiler into wider use because of the definite pressure limitations of boilers of the fire-tube type. The result was that from 1900 on, many water-tube boiler installations were put into operation either as replacements in plants previously equipped with fire-tube boilers, or as new installations. Most of the boilers installed during this period were designed for pressures of from 150 to 160 lb per sq in., although those designed for pressures as low as 125 lb per sq in. were not uncommon.

Many of the boilers installed during this period, even though well maintained, subsequently developed serious defects. That many of these designs were unsatisfactory was not known at the time and, in some instances, serious failures occurred before engineers awakened to the fact that there were definite defects in certain designs. These boilers are now from 25 to 35 years old. Many of those that come under the supervision of state boiler inspection departments or insurance companies have had pressure reductions intended to compensate for the effects of age and long usage, but it is doubtful whether any pressure reduction can compensate for defects of the character that have developed. It appears reasonable to conclude that when a boiler develops defects that can be investigated and completely analyzed, the correction is the elimination of the defect or the discontinuance of the boiler from service. A reduction in pressure of from 10 to 20 per cent cannot compensate for the loss of strength, resulting from the defects that frequently develop. A boiler that is not safe at 160 lb pressure will not be any safer at 140 lb.

Head Failures

The formula upon which the earlier boiler drum heads were designed, even after the adoption of the first A.S.M.E. Code, was found to permit unsatisfactory design, and the code formula was subsequently modified. The destructive head failures that have occurred and the numerous near failures that have been prevented by careful inspection, clearly demonstrate that the earlier head designs must be regarded with suspicion.

It is true that die marks left on the inside surfaces of heads during fabrication, particularly at flange knuckles, have been responsible for the development of many cases of grooving and cracking which have resulted in failures or necessitated replacement, but it is also apparent that a number of these cases of grooving and cracking would not have developed had the design required heads of a form and thickness that would not flex in service.

External Corrosion of Head and Head Seams

Until quite recently, water-tube boilers of the bent-tube type set in battery, were arranged with the inside or blind heads concealed in brickwork. Such construc-

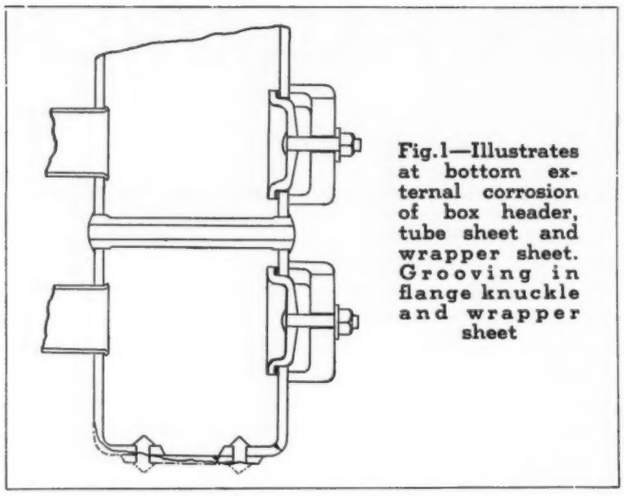


Fig. 1—Illustrates at bottom external corrosion of box header, tube sheet and wrapper sheet. Grooving in flange knuckle and wrapper sheet

tion not only prevents the inspection of the heads and head seams but lends itself to the development of corrosion because of the moisture that may be retained by the brickwork and deposits of ash. This moisture may collect during long shutdown periods, or come from leaking steam lines and leaking tubes. State inspection departments and insurance companies are now insisting that all blind heads concealed in brickwork be arranged so that they can be inspected. If found satisfactory, the possibility of corrosion resulting from dampness may be eliminated by the installation of division plates. Boilers having blind heads concealed in brickwork that have not been subjected to this treatment are of unknown safety.

External Corrosion of Tube Sheets

It is remarkable that there have not been more serious boiler failures resulting from the external corrosion of tube sheets in the drums of water-tube boilers of the bent-tube type. That there are not more failures from this cause is probably due to the discovery of the condition before the tube sheets have wasted away sufficiently to permit failure. It is difficult to remove all of the deposits of ash that lodge on the mud drums of boilers of this type. These deposits of ash, when damp, will cause rapid corrosion of the tubes and tube sheet. Corrosion of this kind appears to attack the tubes just above the tube sheet and the tube sheet surfaces adjacent to the tube holes. The tubes having thin walls in comparison to the tube sheets usually give warning of this condition first. It should be noted that the amount of metal lost through external corrosion of this kind cannot always be properly gaged at the tube hole because the areas slightly removed from the tube holes frequently are the most seriously affected.

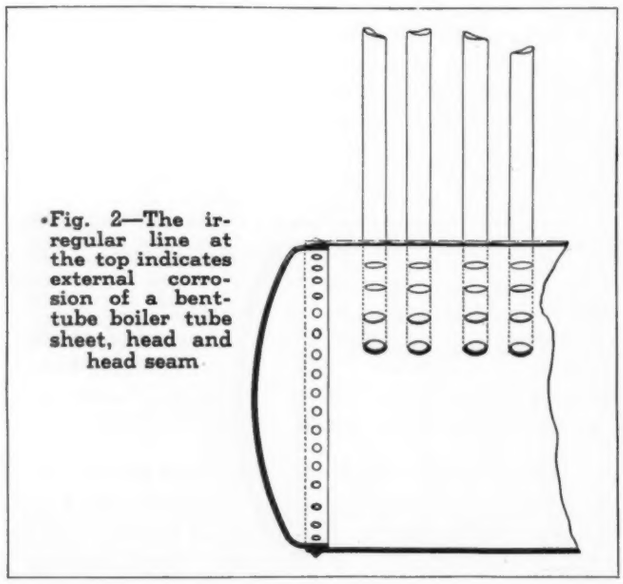


Fig. 2—The irregular line at the top indicates external corrosion of a bent-tube boiler tube sheet, head and head seam

Corrosion of Box Headers

Box headers sometimes develop cases of external and internal corrosion. The brickwork and asbestos or other packing at the sides and under box headers often become water soaked when the tubes are cleaned, or leakage from hand-hole caps may provide a constant source of moisture at these points when boilers are in operation. Over a period of years the areas exposed to such dampness will corrode to a dangerous degree.

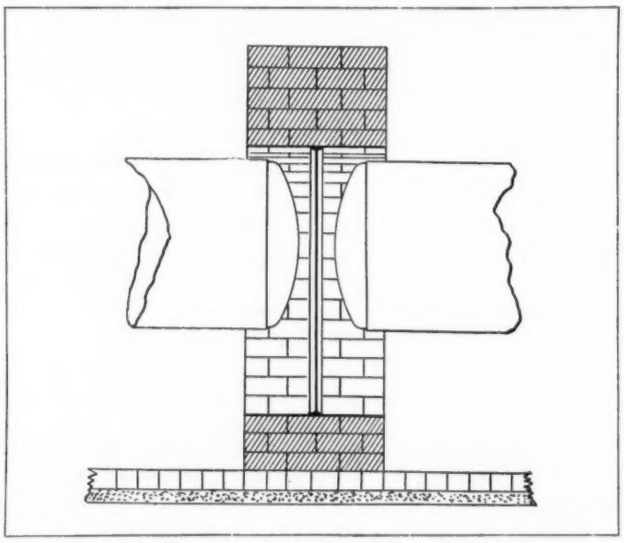


Fig. 3—Division plate in party wall to permit access for inspection of blind heads and to prevent external corrosion

Serious internal corrosion usually takes the form of grooving at flange knuckles and in wrapper sheets adjacent to the flanged ends of tube and end sheets. The grooves in flange knuckles may have their inception in tool or die marks, but this type of defect is usually aggravated by faulty design. The plate used is sometimes found to be too light for the pitch of the header staybolts, which, of course, is determined by the pitch of the tubes. The condition is aggravated when the plates waste away from internal or external corrosion during years of service.

Cracking of Boiler Metal

Without attempting either to defend or to oppose certain current theories regarding caustic embrittlement, it must be admitted that during recent years the necessity of boiler water treatment has been greatly increased and that some water treatments have been followed by serious cases of boiler metal cracking. The increased necessity for boiler water treatment appears to be due to a number of reasons, the principal ones being operation of boilers at higher ratings and the necessity of using

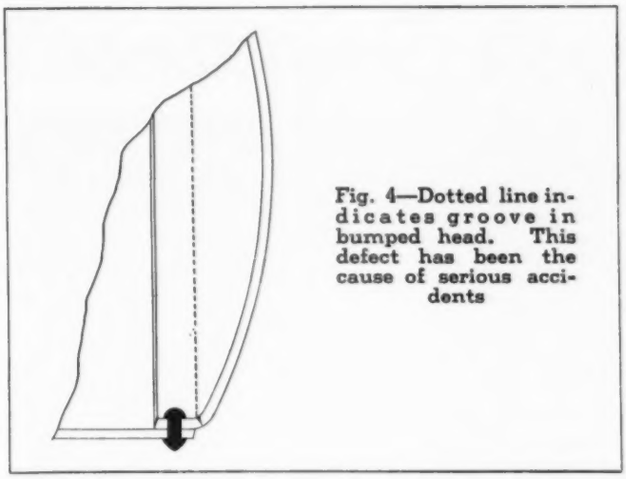


Fig. 4—Dotted line indicates groove in bumped head. This defect has been the cause of serious accidents

water containing increasing amounts of scale-forming solids as the level of the ground water in certain sections of the country has receded. There are undoubtedly many boilers in operation that have cracks in their riveted areas to a greater or lesser degree. Careful inspection and the chemical control of feedwater has prevented many serious failures. The development of leaks in the riveted seams of a boiler should always be regarded as a warning of the possible existence of a serious condition, requiring complete investigation before repairs are attempted.

Repairs and Replacement

Practically all of the defects outlined in the foregoing may be eliminated by proper repairs, but is it economical or desirable to make such repairs in many cases? For example, when a case of blind head corrosion or cracking has been detected in a bent-tube boiler it is not unusual to find serious tube-sheet corrosion, not to mention corrosion of the rear bank tubes. The replacement of a tube sheet or drum necessitates the retubing of the boiler. When this has been done at considerable expense, the plant owner still has a boiler whose pressure will be limited by the age of the drums that were not renewed.

In boilers of the box-header type, locally corroded areas frequently can be satisfactorily repaired by careful welding, but, if the replacement of a header is required, the boiler must be retubed and again the plant owner has made a material investment for major repairs but still has an old boiler.

It is believed, therefore, that the boilers of which we were so proud 20 or 30 years ago, must be regarded with suspicion in so far as their safety is concerned until they have been proven absolutely safe by a thorough and complete inspection. Further, it is evident that when boilers in this group require major repairs, the question of replacement should be given careful consideration.

Half Century of Electrical Progress

Sponsored by the local Chamber of Commerce, Schenectady's Half Century of Electrical Progress was celebrated in that city June 12 and 13 to commemorate the establishment of the electrical industry there by Thomas Alva Edison. It was just fifty years ago on June 14 that Edison took title to two abandoned shops of the McQueen Locomotive Company as a new location for the Edison Machine Works, thus laying the foundation for a local industry which later developed into the present General Electric Company.

To business and industrial leaders from all sections of the country attending the festivities, the outstanding event of the two-day celebration was a dinner on Friday evening for more than 500 invited guests at which the chief speakers were Owen D. Young, chairman of the G-E Board of Directors, Dr. George R. Lunn, New York State Public Service Commissioner, Charles A. Edison, son of the famous inventor and W. S. Barstow, Edison Pioneer and president of the Thomas Edison Foundation. Dr. Dixon Ryan Fox, president of Union College, acted as toastmaster.

At the dinner, Mr. Young called attention to the lesson which the life and work of Edison holds not only for an individual but for an organization or a nation. Remarking on the swift strides of electrical progress, he stated: "So rapidly came invention and improvement, fostered by research, that in this growing art it could never be said today that what is—is. It could only truthfully be said that what is—is not, in the sense that what is, is too obsolete. The whole history of the 50 years shows that what is not—can be, and will be."

In his talk, Dr. Lunn traced the development of the electrical industry and its relationship to present-day improved standards of living, and then drew upon a conversation he once had with Steinmetz and Marconi to point a prophesy that electrical progress is still, as Marconi put it, "in the kindergarten class."

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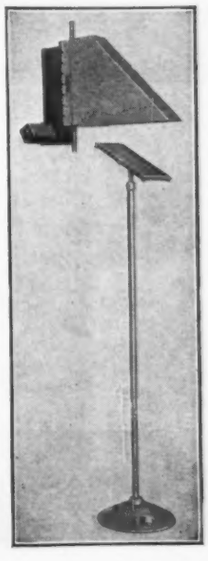

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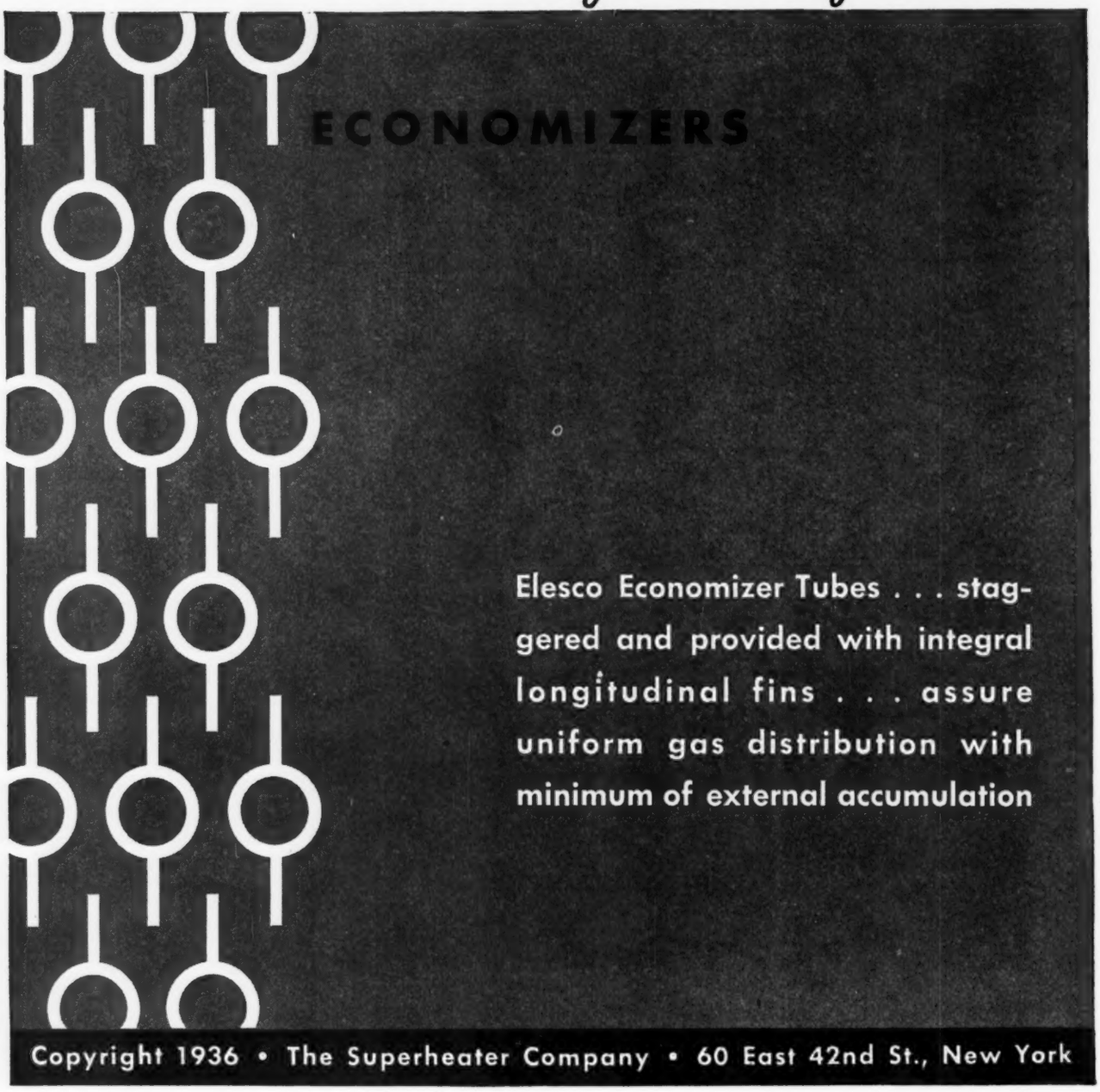
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Experience with Combustion Control

When Burning Natural Gas, Fuel Oil, Acid Sludge and Petroleum Coke Breeze

By T. E. CROSSAN† and
A. J. MATHERNE, Jr.††

In this paper, presented at the Dallas Meeting of the A.S.M.E. on June 17, 1936, the authors describe the combustion control system installed to operate on the natural gas and give operating experiences when the fuel averages 70 per cent natural gas and the remainder petroleum coke breeze and acid sludge. Fuel oil is used when the natural gas supply is interrupted.

THE plant is located in Baton Rouge, La., and furnishes steam and electricity to a large oil refinery and a chemical plant, the surplus electrical energy being sold to a local electric company.

The major equipment consists of five 350,000 lb per hr boilers operating at 620 lb per sq in. pressure at the superheater outlet and 725 F steam temperature, and three 15,000-kw non-condensing turbine-generators exhausting to process at 135 lb. The flue gas, after leaving the boiler, passes through an economizer and then through a plate-type air heater. Two induced-draft fans and one forced-draft fan furnish the necessary air for combustion, the temperature of the air for combustion ranging from 320 to 375 F, according to the boiler rating. All major auxiliary equipment is driven by steam turbines.

At this writing the steam demand averages 800,000 lb per hr and the electrical demand 16,000 kw.

Fuels Burned

Natural gas makes up about 70 per cent of the fuel, while petroleum coke breeze and acid sludge make up the remainder. Approximate analyses of the fuels are as follows:

Petroleum Coke	Per Cent
Volatile matter	11.06
Fixed carbon	87.80
Ash	1.14
Sulphur	2.24
Moisture	8.00
Btu per lb	15,294
Natural Gas	
Carbon dioxide	0.10
Oxygen	0.40
Nitrogen	1.50
Methane	95.65
Ethane	1.13
Propane	0.73
Iso-butane	0.35
Pentane and heavier	0.14
Btu per cu ft	985

Acid Sludges	Lubricating Acid Sludge	Acid Tar
Specific gravity, as received	1.084	1.052
Moisture or weak acid, per cent	39.68	47.51
Acidity of weak acid, per cent	32.58	32.21
Acidity of sludges, per cent	12.95	16.73
Weight per gallon, pounds	9.03	8.76
Heating value, Btu per pound	10,940	9525

Fuel Oil
Bunker "C" class fuel oil

Each boiler is equipped with a steam flow-air flow meter, six-point draft gage, CO_2 and CO recorder and six-point temperature recorder, as well as the usual steam and water pressure gages and thermometers.

Description of Control

This consists of oil-pressure-operated regulators located at the control points of each boiler auxiliary, valve, etc., actuated by pneumatic loading from a common boiler master controller. Each boiler master controller is similarly under the control of a supermaster controller, the function of which is to transmit, to the individual boiler master controllers, loading pressures equivalent to changes in the demand for steam as indicated at the supermaster by inverse variations of the main steam pressure. The master controllers afford a centralization of control and adjustment in the relation between the various elements. Those pertaining to an individual boiler are adjusted at the boiler master and the distribution of the total station load is adjusted at the supermaster. The supermaster also controls the boiler feedwater pump regulators which govern the speed of the pumps to maintain an excess pressure proportional to the steam demand.

Oil at 100-lb pressure to operate the regulators and air at 5-lb pressure for the master loading pressures are supplied by a motor-driven power unit and a steam-driven power unit consisting of positive displacement

† Superintendent, Louisiana Steam Generating Corp.
†† With Louisiana Steam Generating Corp.

blowers and rotary gear oil pumps. Normally the motor-driven power unit is used, and, in case of electrical trouble with this unit, the steam-driven unit automatically comes in service when the oil pressure drops to 65 lb, thereby maintaining oil pressure to the regulators at all times.

The supermaster controller is the central point for the entire plant. It furnishes master loading pressures for individual boilers, and is equipped with steam-pressure control and manual control.

The boiler master controller is used in conjunction with the supermaster controller. It is provided with three regulator loading elements for loading the fuel regulators and the air and fuel corrector regulators.

The induced-draft fan regulator, or air regulator, is of the piston type with a master loading diaphragm and compound diaphragm top. It is arranged to control the speed of the turbine driving the induced-draft fan so as to obtain a draft in the last pass of the boiler which will be proportionate to a loading pressure imposed by the boiler master. The regulator is arranged to control the desired uptake draft by operating the admission valves in the turbine steam chest. These valves are operated by means of an oil-operated relay cylinder or piston which is controlled by a pilot valve on the regulator.

The forced-draft fan regulator, or furnace draft regulator, is of the piston type with a compound diaphragm top. It is arranged to control the speed of the turbine driving the fan so as to obtain a draft in the furnace proportional to a weight loading on the regulator. It is not loaded by the boiler master controller. It is weight loaded to balance the desired furnace draft which acts on a large area compound diaphragm top.

The fuel (natural gas) regulator is also of the piston type with differential diaphragm top and master loading diaphragm, and is arranged to control a chronometer valve to obtain a certain differential across an orifice in the fuel line which will be proportional to a loading pressure imposed by the boiler master controller.

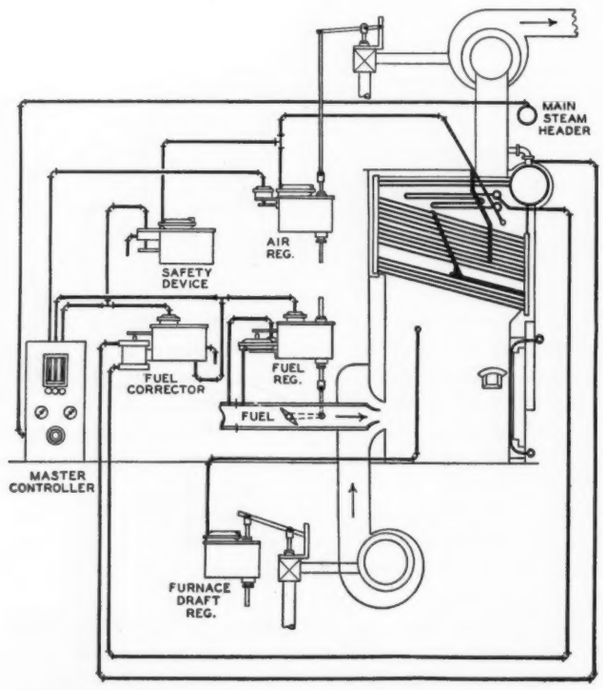

Fig. 1—Diagram of combustion control system

With a uniform quality of fuel and constant ratio of fuel and air, there exists in the system of control, a definite proportion between master loading pressure and the heat input to the furnace. Under normal conditions, the heat input should manifest itself in a proportional evaporation of steam of which the differential between the boiler drum pressure and the superheater outlet pressure is a direct function.

The fuel corrector balances master loading pressure against a differential of drum pressure and superheater outlet steam pressure. Variations in the ratio of these pressures are employed to indicate variations in the fuels not under control. These variations actuate the fuel corrector to adjust the master loading pressure imposed upon the gas regulator in such a way as to increase or decrease the gas supplied to the furnace in amounts equivalent to variations in the fuels not under control.

The safety regulator automatically shuts off the fuel supply in the event of failure of the induced-draft fans. When the safety regulator has opened the air valves and tripped the gas and oil valve switches, it will require manual reset before fuel can again be supplied to the furnace.

The boiler-feed-pump regulator is of the piston type having a master loading pressure diaphragm and a high-pressure steam and water element. Its purpose is to regulate an excess of feedwater pressure in the header above that in the boiler drum and vary this excess with changes in boiler rating in direct proportion to the square of the rating or volume of steam evaporated. The regulator is arranged to control the feedwater header pressure by operating a regulating valve in the steam supply line to the turbine driving the pump. This valve is operated with oil which is controlled by means of a pilot valve on the regulator. Float-operated feedwater level regulators are installed in the feedwater lines at the boiler drums.

Operating Experiences

The pressure on the main steam header can be made to give any amount of swing or compensation desired by adjustment of the supermaster controller. Normally the pressure on the main steam header varies approximately 2 lb, which is considered proper without swinging the boilers too much.

Normally, the combustion control system at this plant is used on all the boilers in service, but frequently one boiler is placed on manual control in order to maintain a constant or steady load for test purposes, certain load conditions, etc. The control cannot be used to bring a boiler into service. The boiler must be brought into service manually, up to about 20 per cent of capacity; then the control can be put in service and used up to 100 per cent of boiler capacity.

All five of the boilers are equipped to burn natural gas and fuel oil. Four are equipped to burn acid sludges in addition to natural gas and fuel oil, and two to burn petroleum coke breeze in addition to the other fuels. Usually, petroleum coke breeze and natural gas are burned under two of the boilers, acid sludges and natural gas under two and natural gas only under one.

Fuel oil is used as a standby fuel and is burned only when there is no gas available. Whenever this occurs the boilers are controlled manually.

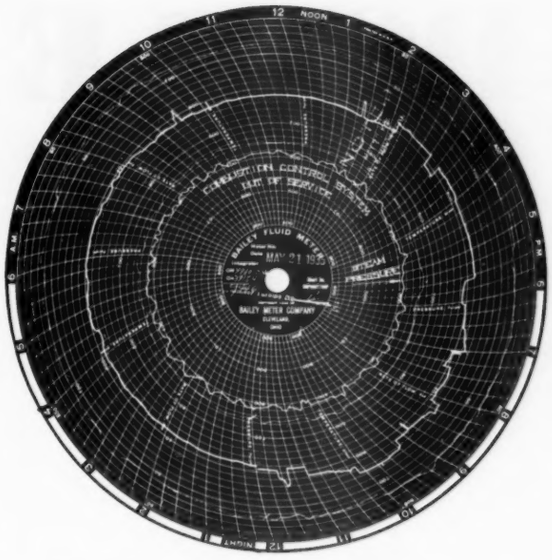

Fig. 2—Steam header pressure for 24 hr with combustion control system out of service

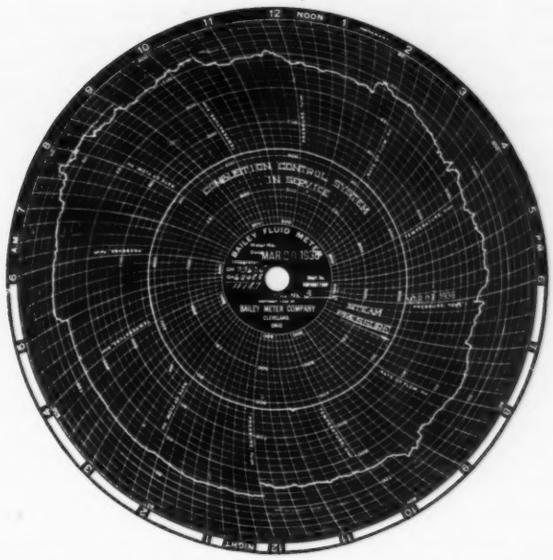

Fig. 3—Steam header pressure for 24 hr with combustion control system in service. Note steady steam pressure

Natural gas being the only fuel that is controlled by the combustion control system, the percentage burned with other fuels under each boiler varies from 50 to 90 per cent of the total and the minimum amount of natural gas under each boiler with other fuels that will be controlled properly by the control system is approximately 40 per cent of the total.

The fuel corrector adjusts the ratio of the natural gas to total air in order to compensate for quality and quantity of other fuels not under such control.

The induced-draft fan regulators are very sensitive and fast and have ample power for regulation of the air.

The forced draft fan regulators, or furnace-draft regulators, are adjusted to maintain a furnace draft 0.05 in. of water under all loads and are very sensitive to draft changes. The temperature of the air for combustion as supplied by the forced-draft fans varies from 320 to 375 F, depending upon the rating.

Correct excess air for proper combustion efficiency is determined by periodic flue gas analyses and with the aid of CO_2 and CO recorders. The fuel-air ratio is changed manually by means of bleed valves on the boiler master controller until the CO_2 and CO recorder indicates a maximum of CO_2 with no CO. Whenever there is a deficiency of air in the combustion chamber, the CO_2 and CO recorder will indicate this condition; then, by means of the bleed valves on the boiler master controller, it can be corrected.

From flue gas analyses, it has been found that, for different fuel burning combinations, the following excess air gives the best combustion efficiency.

Fuel Burning Combination	Per Cent Excess Air
100 per cent natural gas	10
90 per cent natural gas with 10 per cent coke breeze	25
80 to 60 per cent natural gas with 20 to 40 per cent acid sludge	18 to 25
80 to 60 per cent natural gas with 20 to 40 per cent fuel oil	15 to 20

The fuel correctors have a tendency to swing load considerably on the boilers and, in order to stop this swinging, the dashpots have to be almost closed off, making the corrector slow to operate. Whenever the quality or quantity of the uncontrolled fuels increases rapidly, the furnace has a deficiency of air. When this happens, the pressure drop across the superheater decreases, actuating the fuel corrector, causing it to further increase the amount of fuel to the furnace and increasing the amount of deficiency of air. This necessitates bleeding down the corrector loading pressure manually until proper conditions exist in the furnace as indicated by the steam flow-air flow meter.

No considerable attention is required to keep the control in good working order, although a maintenance schedule on control equipment is followed. This calls for periodic inspection of all control equipment.

Trouble was experienced with pipe scale or rust being blown out of the loading-pressure iron pipe line into the throttle valves and cup valves on two of the boiler

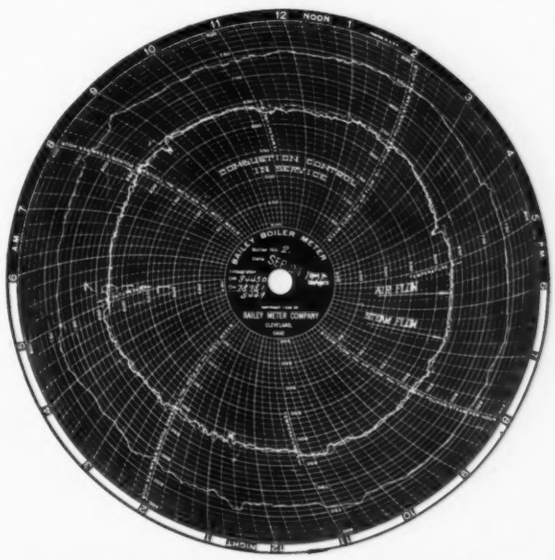

Fig. 4—Steam flow-air flow meter chart and CO_2 and CO recorder chart for 24 hr. Boiler burning natural gas and petroleum coke breeze from 12:00 a.m. until 10:50 a.m. and natural gas, petroleum coke breeze and acid sludge from 10:50 a.m. until 12:00 p.m.

master controllers. At times this scale would completely stop the supply of the loading pressure air and shut down the regulators in service. This trouble was eliminated by the installation of brass pipe for loading pressure air. Also, due to the network of oil piping in the system, considerable leakage is found in the lines which is hard to stop.

The fuel corrector pressure element is more or less a manometer in design, with boiler drum pressure on on leg and superheater outlet steam pressure on the other, with mercury as the weighing medium, the drum pressure being taken off the water column. Mercury was blown out and lost from two of the fuel corrector-pressure elements due to the operators cutting out water columns for repairs without first cutting off the steam-pressure valves at the regulator. This drum-pressure connection should be taken off the drum proper to eliminate loss of mercury.

Occasionally, the supermaster and the boiler feed-pump regulator pressure elements are thrown out of adjustment and balance by operators cutting steam pressure leads in and out of service. When this occurs, it is necessary that the regulators be readjusted and rebalanced before they can be restored to service.

All piston type regulators have dashpots which use oil for stabilizing the regulators. The troublesome feature of this device is that dashpot adjustments have to be made to compensate for changes in viscosity of oil every time the room temperature changes approximately 20 F.

No trouble has been experienced with the control due to the flue gas passes between the boiler tubes clogging as all control pressures are positive and do not use differential pressures across any part of the boiler gas passes to load the regulator. Compensation for fouling in the flue gas passes can be made, however, on the boiler master controller to give the proper fuel-air ratio.

No trouble has been experienced with failure of leather diaphragms of loading-pressure elements and compound top elements. All leather diaphragms are lubricated periodically with "neetsfoot" oil to keep the diaphragms soft and pliable so that operation will not be sluggish with changing loads or loading pressures.

The control system, as installed, has a safety feature to insure oil pressure to the regulators at all times, but no provision has been made for continuity of air pressure. Should the air pressure in the system fail, it would be the same as bleeding down all the loading pressure elements to the regulators, which, in turn, would close down these regulators. A desirable feature in the system would be air pressure for loading the regulators at all times or such an arrangement of regulators that they would not move should the air pressure fail. Another desirable feature would be some means of keeping the regulators in fixed position should both air and oil pressure or the air or the oil pressure to the individual regulator fail.

The boiler feed-pump regulators are adjusted to give an excess pressure of about 80 lb above steam pressure and to vary this pressure with changes in boiler rating in a relation directly proportional to the square of the rating or volume of steam evaporated. When two- or three-pump operation is necessary, the regulators are adjusted to give each pump the same inlet steam pressure. This turbine inlet pressure is maintained equal on all turbines in service with swings of pump load.

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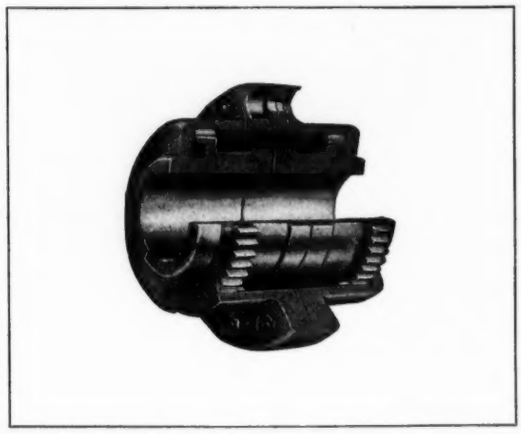

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STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Tests on High-Pressure High-Temperature Turbine

Brown Boveri Review of May 1936 contains the results of a test by Professor Josse on the high-pressure turbine at the Karoline Mine of the Witkowitzer Bergban and Eisenhütten-Gewerkschaft in Czechoslavakia. This is a 36,000-kw machine operating at 120 kg per sq cm (approximately 1700 lb per sq in.) and a steam temperature of 480 C (896 F) and is said to be the largest turbine now operating in Europe under such high pressure and temperature. It has been in service for several years.

It is a three-cylinder machine, the low-pressure cylinder being of the double-flow design. The first high-pressure stage consists of a Curtis wheel having two rows of blades while all the following stages work on the reaction principle, there being 32 reaction stages in the high-pressure element, 18 in the intermediate and 6 in each half of the low pressure element. It is built for intermediate superheating up to 360 C (680 F) at the inlet to the intermediate cylinder and with two extraction points for feedwater heating, only that on the low pressure cylinder being used in service. The rotative speed is 3000 rpm.

The materials employed in the construction of the high pressure element are molybdenum cast steel for the cylinders; nickel-chromium steel for the runner; nickel steel for the high-pressure nozzles and chrome steel for the other stages; nickel-chromium-molybdenum steel for the blades of the Curtis wheels and chrome steel for the blades of the other stages.

The intermediate element has a cast steel cylinder, the runner is of nickel-chromium steel; and the 1st to 13th stage blading is of chrome steel while the 14th to 18th stage blading is of rust-proof steel. In the low-pressure element cast steel is used for the cylinder; nickel-chromium steel for the runner, chrome steel for the blading of the first two stages and rust-proof steel for that of the last four stages.

Tests were made with and without intermediate superheating and also with and without feedwater heating by extraction steam, so that the thermal gain from these could be calculated. The available load did not permit testing at over 25,000 kw although the machine was designed for the most economical rating at 30,000 kw. The tests were conducted at 25,000 kw and 19,000 kw.

With inlet steam at 120.7 kg per sq cm (1716 lb per sq in.) and 477 C (890.6 F), intermediate superheating at 350 C (662 F) and condensate heating to 86.2 C (187 F), a specific steam consumption of 3.22 kg per kwhr (7.08 lb per kwhr) was obtained at a load of 26,050 kw, both figured *at the generator coupling*. The corresponding heat consumption was 2477 kg cal per kwhr (9829 Btu per kwhr) and the thermal efficiency 34.72 per cent.

When tested with intermediate superheating, but without extraction, under practically the same initial steam conditions and a load of 26,522 kw the steam consumption was 3.16 kg per kwhr (6.95 lb per kwhr), the heat consumption 2593 kg cal per kwhr (10,289 Btu per kwhr) and the thermal efficiency 33.17 per cent.

On the third test, without either intermediate superheating or extraction, and a load of 23,822 kw, the steam consumption was 3.487 kg per kwhr (7.67 lb per kwhr), the heat consumption 2634 kg cal per kwhr (10,452 Btu per kwhr) and the thermal efficiency 32.65 per cent.

From these figures it will be noted that the intermediate superheating and extraction account for an appreciable gain in efficiency. It should be noted that, following European practice, the calculations were all based on the load measured at the generator coupling. The corresponding loads at the generator terminals were respectively 24,940, 25,411 and 22,656 kw.

Increased Electric Output in British Empire

While the output of central power stations in Great Britain increased 12.4 per cent in 1935 over that for 1934, this was exceeded by the average increase in British overseas possessions. According to a tabulation in *The Electrical Times* (London) of June 11, the output of stations in South Africa increased 14.25 per cent, those in Australia and New Zealand 11.6 per cent, those in India 10.9 per cent, those in Canada 4.45 and those in miscellaneous possessions 20.4 per cent. This makes an increase of 13.56 for the colonies or 13.33 per cent for the whole British Empire. These figures considered in conjunction with the present growing load in the United States indicate a world-wide trend toward much greater use of electricity in both industry and domestic applications.

Closed-Air System of Transmission

Transmission of power by compressed air has long been used to meet special conditions but, because of its relatively poor economy, it has been displaced by electricity wherever possible. However, a new "closed-air" system introduced by O. E. Jorgensen and recently tested in a plant by G. & J. Weir of Glasgow is of interest because of its apparent increased economy. This system is described in the June issue of *Engineering and Boiler House Review* (London) which says:

"The essence of the matter is that when free air is compressed to about 100 lb per sq in. its rise in temperature of 360 deg F represents power which is entirely wasted in most cases, but when air at 200 lb pressure is further com-

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pressed to 300 lb and used in a plant exhausting back to the compressor at 200 lb, the rise in temperature of about 55 deg is relatively small and the power represented by the heat need not be altogether lost. In both cases the available effective pressure is the same, but there is clearly a large difference between the economy of the two methods. Furthermore, the compressor ratio in the first case is 7.8 but in the second it is only 1.47 and this means a much smaller compressor for the closed-air system."

Experiments to date indicate that an efficiency of 75 per cent may be expected with this system.

Performance of British Power Stations

The accompanying tabulation, reproduced from *The Fuel Economist* of June, gives the overall thermal efficiencies of all British power stations showing over 20 per cent efficiency, as contained in the recent report of the Electricity Commissioners for the year 1935.

It will be noted that a new record in efficiency of British power stations was attained by the Battersea Station of the London Power Company which averaged 28.59 per cent for the year. In 1934 the list was headed by Barking "B" at 27.95 per cent, Battersea then coming second with 27.24 per cent. Barking also improved over its 1934 performance by reaching 28.07 per cent.

	Units generated	Fuel Consumption lb. per unit.	Thermal Efficiency per cent.	Annual Station Load Factor per cent.
Battersea(London Power Co.)	797,749,600	0.96	28.59	68.1
Barking, B.	875,701,000	1.09	28.07	66.6
Dunston, B.	406,281,800	1.11	27.25	39.4
Clarence Dock, L'pool	386,321,370	1.12	26.21	65.2
Ironbridge (W. Midlands J.E.A.)	310,430,600	1.42	25.59	66.6
Blackburn Meadows, Sheffield (New)	178,400,550	1.16	24.47	77.0
Spondon (Derby & Notts. E.P. Co.)	362,408,770	1.37	23.97	59.8
Kearsley (Lancs. E. P. Co.)	401,961,360	1.17	23.95	75.5
Deptford West (London Power Co.)	587,104,530	1.30	23.89	54.1
Hams Hall (B'mingham Corporation)	452,816,800	1.34	23.41	53.8
Brimsdon, B.	346,226,300	1.42	22.89	34.7
Kirkstall, Leeds	231,901,400	1.35	22.63	57.3
Portishead, Bristol	251,122,690	1.10	22.52	59.3
Portobello, Edinburgh	311,057,900	1.44	22.19	34.8
Barton, Manchester	632,490,500	1.29	22.10	58.2
Hackney	177,139,900	1.37	22.07	41.3
Brighton Corp.	190,400,800	1.27	21.97	36.7
Barking, A.	765,743,000	1.41	21.78	37.7
Thornhill (Yorkshire E.P. Co.)	217,920,140	1.36	21.77	43.1
Sculcoates, Kingston-upon-Hull	238,405,000	1.52	21.55	40.8
Lots Rd. (L.P.T.B.)	412,709,300	1.42	21.45	43.9
Furybridge (Yorkshire E.P. Co.)	237,419,000	1.39	21.34	66.8
North Tees	212,835,060	1.37	21.03	35.0
Croydon Corp.	156,835,200	1.41	20.72	32.0
Battersea B. Council	61,453,120	1.46	20.72	17.7
Chadderton (Oldham Corporation)	107,406,700	1.44	20.68	32.7
Derby Corporation	73,763,310	1.70	20.67	31.2
Lister Drive, L'pool	185,986,150	1.50	20.66	38.8
Neasden (L.P.T.B.)	135,824,700	1.33	20.57	40.0
Hartshead, Stalybridge	110,915,500	1.45	20.56	40.6
Yoker (Clyde Valley E.P. Co.)	169,264,900	1.41	20.24	38.2
Padiham (Lancs. E.P.Co.)	56,904,971	1.40	20.12	38.2
Greenwich (L.P.T.B.)	250,489,700	1.46	20.06	49.8
Leicester Corp (Central)	214,167,060	1.75	20.05	39.6

Increased load factor figured in the better performance of certain stations, the output of steam stations having increased nearly two billion kilowatt-hours over the preceding year. Moreover, twenty-seven stations were responsible for 60 per cent of the total output.

Heat Loss with Bare Flanges

Results of an investigation on the heat loss through uninsulated pipe flanges is given in *Wärme u. Kälte Technik*. This shows for a pair of flanges of a 100 mm. (approximately 4 in.) inside diameter pipe the following values with different temperature differences between pipe and surrounding air.

Temp. dif. deg F	90	180	360	540	720
Heat loss with saturated steam, Btu per hr	317	809	1809	4293	6718
Heat loss with superheated steam, Btu per hr	254	647	1448	3432	5377

The heat loss is approximately proportional to the diameter of the pipe, hence from the above it is possible to estimate the loss from any size pipe.

The next step in the investigation was to insulate the flanges with several different thicknesses and kinds of covers, and the following ranges in heat loss were measured for the corresponding temperature differences.

Temp. dif. deg F	90	180	360	540	720
Heat loss range depending on insulation, Btu per hr	31–113	75–334	206–679	389–1321	599–2024

While the heat loss from bare flanges was appreciably greater when using saturated steam than when employing superheated steam, it was found to be practically the same with saturated and superheated steam when the flanges were well insulated.

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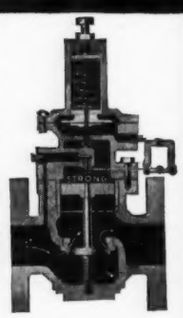

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